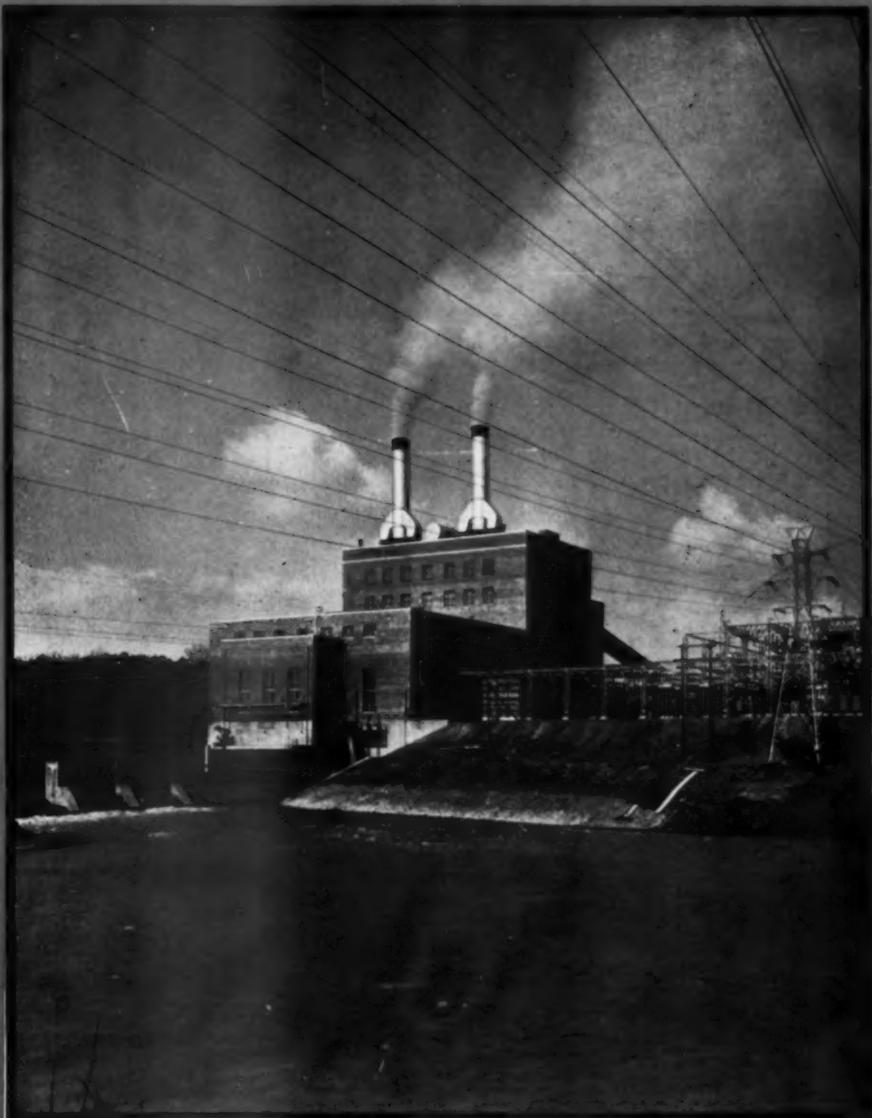
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May, 1950



Dan River Generating Station of Duke Power Company to be dedicated June 7.

Coal Handling at West Central Heating Plant ›

A.S.M.E. Spring Meeting ›

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Vol. 21 **No. 11**

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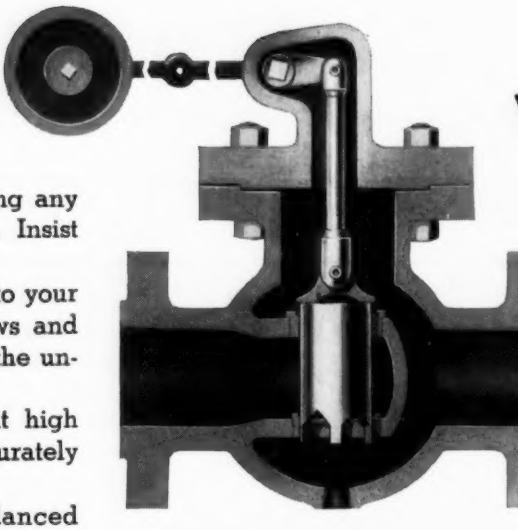

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COMBUSTION

Editorials

An Excellent Selection

Compared with some cities, the smoke problem in New York City is not bad. Except in the larger plants anthracite or oil are extensively burned, and most of the larger plants that burn bituminous coal are equipped for minimum stack discharge. The city has long been free from locomotive smoke, but encounters some from harbor craft and considerable from incinerators. Heavy automobile and bus congestion, especially when engines are idling at traffic lights, undoubtedly contributes much to atmospheric pollution; and periodic fogs tend to accentuate the situation. Nevertheless, there are frequent smoke violations which leave much room for improvement within the scope of control.

In line with the current nation-wide movement on the part of public agencies, stimulated by newspaper campaigns, to clear up atmospheric conditions surrounding our principal cities, the New York City administration, with the cooperation of the A.S.M.E., has tackled the problem. In doing so, a wise beginning has been made in the selection of William G. Christy as director of the newly created Smoke Control Bureau.

Mr. Christy has had a long and successful experience in handling smoke abatement enforcement, first in St. Louis and later for a number of years in Hudson County, N. J., just across the river from New York. Moreover, he is a well-known engineer and has been accustomed to apply an engineering approach to the problem.

New York City is to be congratulated in having secured his services.

What Price Common Sense?

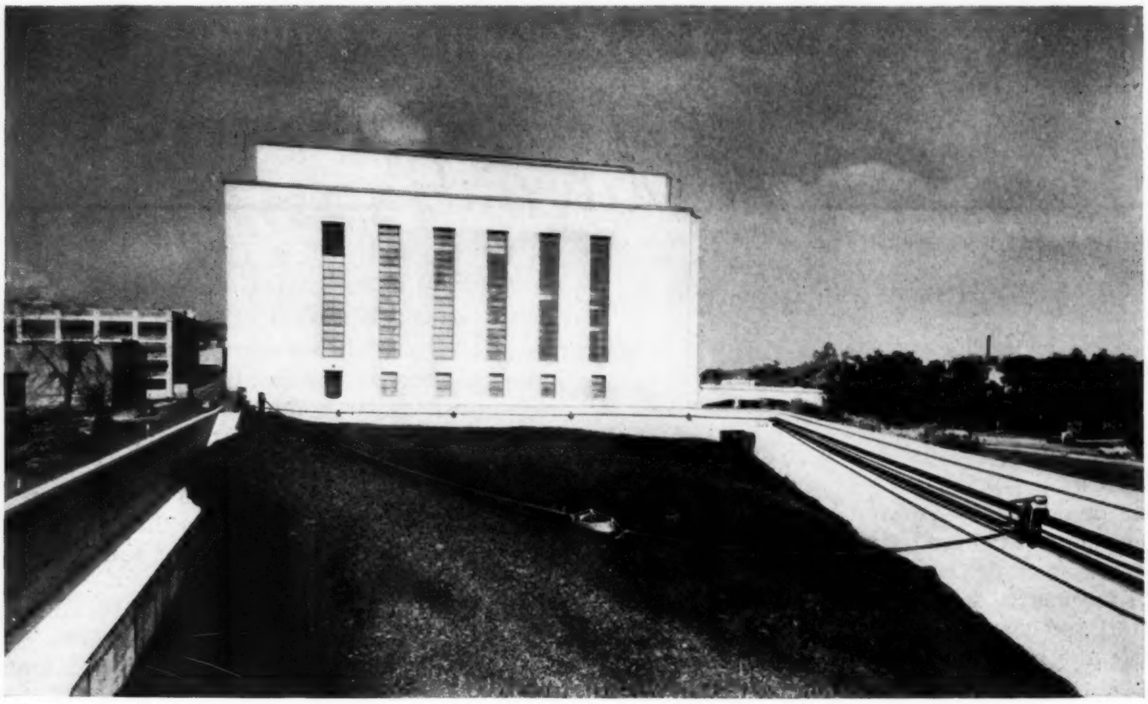
Recent proposals that probability methods be applied to problems of determining utility system reserve capacity deserve serious consideration and careful analysis. Since the engineer has long had available for use the mathematical knowledge required to compute probabilities, the question naturally arises, why hasn't he applied these techniques more widely in making decisions for power system expansion?

A consideration of some of the underlying theories of probability may be helpful in attempting to answer the preceding question. The classical theory can be visualized from familiar examples: there is a probability of one half ($^1/_2$) that a "normal" coin, when flipped, will fall head up, and there is a probability of one sixth ($^1/_6$) that the throw of an "unloaded" dice will result in a "three." In essence, this means that the occurrence of one possible instance precludes the simultaneous occurrence of all others.

The frequency theory of probability is concerned primarily with actual and empirically determined frequency distributions and not with alternatives that are assumed to be equally possible, as in the classical theory. A familiar example of the frequency concept is the actuarial tables used by insurance companies in setting rates based upon life expectancies. The basic conception of this theory involves frequency distributions of large numbers, assuming random samples so selected that any one item has the same chance of being taken as any other. A limitation of the frequency theory is that it pertains to classes of events or classes of items only, and most proponents repudiate the idea of a probability for single cases.

A third theory of probability is, in effect, an approach to the use of common sense, for the so-called "truth probability" pertains to the degree of adequacy of the evidence and its weight relative to a given hypothesis or—in more familiar terms—an engineering alternative. As explained by W. H. Werkmeister in "The Basis and Structure of Knowledge," this theory is based upon decisions "guided in all essentials by the experience of the expert in his field and by the general reliability of scientific method."

Consider for a moment the reality of the manner in which decisions are made to carry out utility system expansion. The numerous variables that have been the subject of intensive preliminary studies have been analyzed and synthesized to the point that those few remaining may be expressed as alternatives. These are, for the most part, subject to interpretation on the basis of financial outlays. Since conditions comparable to the underlying assumptions of the classical and the frequency theories of probability are no longer an accurate statement of the problem in its final state, is it not a fact that the "truth" theory of probability is the one most applicable? And isn't it equally true that it takes a lot of abstruse calculation to equal a little common sense?



West Central Heating Plant with 16,000-ton coal yard and power drag scraper shown in foreground.

Coal Handling at West Central Heating Plant

By STANLEY C. MARSHALL

Sauerman Bros., Inc.

West Central Heating Plant in Washington, D. C., with a potential of 1,320,000 lb of steam per hour to add to the central heating supply for government buildings, was constructed at a cost of about $5,000,000 and went into operation two years ago. Designed to conform to the capital city's standards for beauty and cleanliness, the plant serves to heat approximately 125 public buildings.

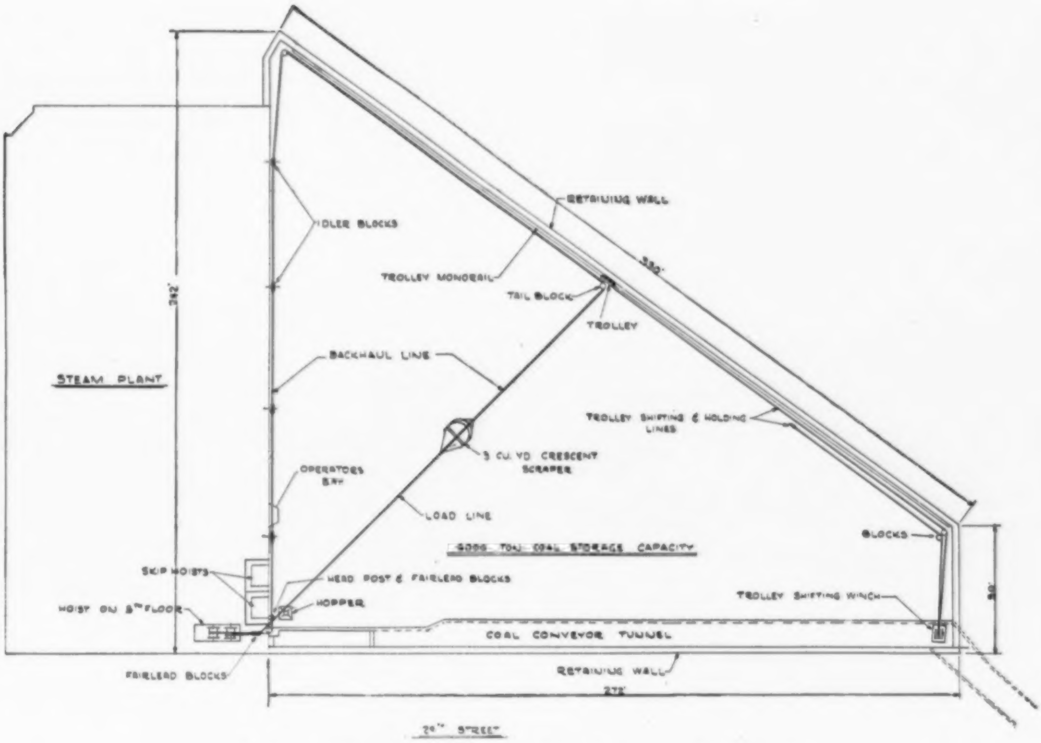
The building is five stories high with the boilers reaching from basement to the fourth-floor level. Although four water-tube boilers are installed now, ultimately there will be six, each with 25,000 sq ft of heating surface. Operating pressure is 250 psig and design pressure is 400 psig. The boilers are rated at 220,000 lb of steam per hour with a maximum of 240,000 lb.

Coal is brought to the plant by rail in hopper-bottom dump cars. The receiving building is across K Street from the plant, and the coal is dumped into a hopper which feeds a 150-ton per hr Link-Belt conveyor running under the street to the plant. A "grizzly" at the hopper sorts out oversize. The conveyor runs the coal through a tunnel and feeds through a breaker either to skips for delivery directly to the top of the plant, or to a swivel stacking conveyor which builds an initial pile for storage handling by a power drag scraper.

The coal storage area is roughly triangular, as may be seen in the plan layout, and is bounded by an elevated highway on one side and a residential street on the other. Proportions of the available space indicated that a coal storage machine which could adapt itself to an oddly shaped area should be used. Factors in the choice of a drag scraper included the location of the plant in a residential area, as well as the restrictions against dirt and noise which are in effect in the city of Washington.

A 22-ft high stone and concrete retaining wall runs around the storage yard, which has a shape approximating that of a right tri-

The adaptability of the power drag scraper to handle coal without objectionable noise and dust and to meet conditions imposed by an oddly shaped area is explained in this description of coal-handling facilities at a new government central heating station in Washington, D. C.



Layout of heating plant and coal storage facilities.

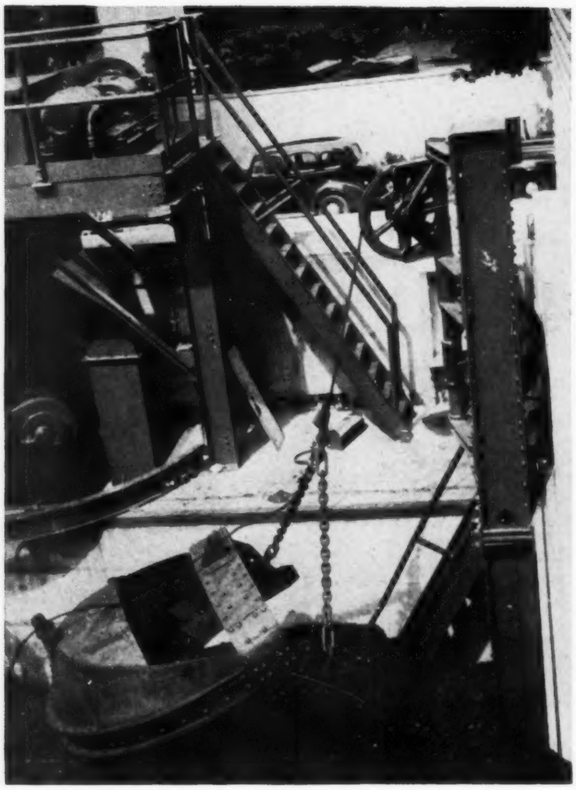
angle having its base resting along the boiler house wall. A 3-cubic yard Sauerman power drag scraper fills the 16,000-ton storage area and reclaims the coal as needed, performing both operations at 100 tons per hr on its average haul of 130 ft. Coal is piled to a depth of 19 ft.

The scraper works between a headpost, adjacent to the stacking conveyor, and a tail block carried on a trolley which rides a monorail the length of the "hypotenuse" wall, a distance of 325 ft. The inhaul and outhaul of the scraper and the movement of the tail block by the monorail and trolley system are remotely controlled by a single operator, housed in a comfortable cab on the side of the plant and overlooking the storage area.

Lack of available space demonstrated the versatility of this type of machinery. The hoist for the scraper, for instance, could not be located in the storage area, but was placed instead on the fifth floor of the plant, above the boilers. Electro-hydraulic controls run from the operator's cab to the 100-hp, two-drum Sauerman hoist and the reeving of operating cables from the storage area to the fifth floor of the plant posed an interesting engineering problem. The hoist drive motor is a totally enclosed, explosion-proof, squirrel-cage unit.

The shifting winch for the tail block trolley is located at the apex corner of the storage yard, and is powered by a 10-hp, squirrel-cage, explosion-proof motor. The operator's cab contains the electric winch controls.

Cab on wall at upper right houses scraper operator and controls; the stacking conveyor for feeding coal to storage is shown on the left.



View of scraper dumping loads over hopper.

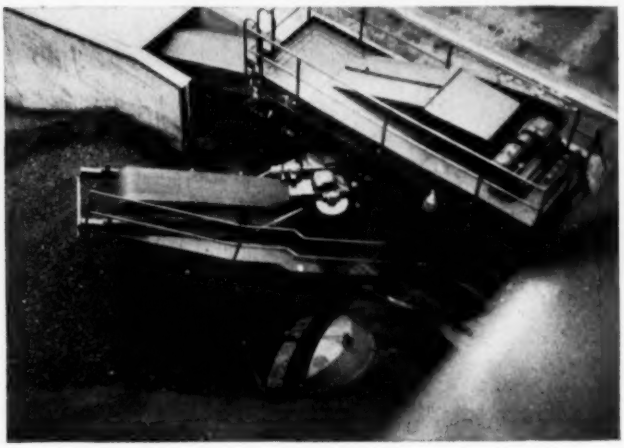
The scraper travels at 350 ft per minute inhauling and outhauling, and easily stocks out normal receipts of seven carloads of coal in seven hours. Since all operations are remotely controlled, the operator need never shut down, for all operations are at his fingertips.

Coal is reclaimed to a hopper at the foot of the headpost, and is conveyed directly to the top of the building for distribution to the bunkers of each boiler. For this the same skip conveyor is used as for coal which bypasses storage. Before passing into the bunkers it is moved over continuous weighers.

The bunkers feed water-cooled stokers, each of which is capable of burning 14 tons of coal per hour. Unburned particles of coal dust, after being collected in electrical precipitators, are returned to the furnace for reburning.

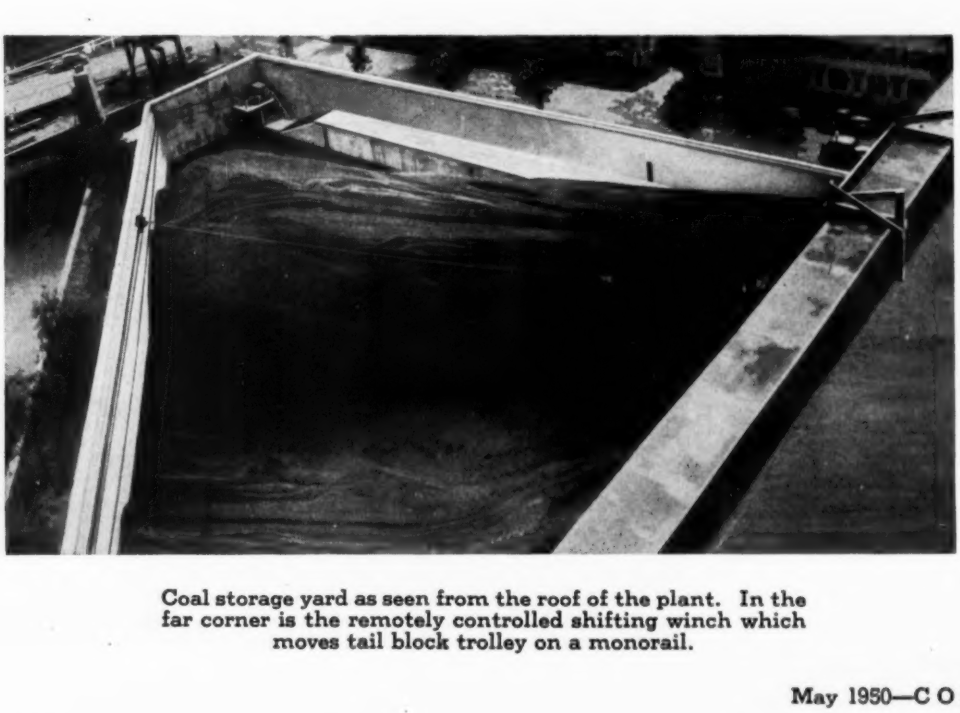
Ashes from the furnaces are sluiced with water and pumped through pipes running back through the same tunnel as is used to bring in the coal. At the coal-receiving and ash-handling plant, the ashes are precipitated and carted away.

The plant which furnishes its own power for operation of electrically driven machinery and lighting load was designed by engineers of the Public Buildings Administration.



From the tunnel shown in the upper left coal passes to the breaker on the right and then to the swivel stacking conveyor which builds the initial pile for the storage drag conveyor.

Although work on the plant was started in 1942, it was suspended almost immediately because of the war. Construction was resumed in February 1946 by the Charles H. Tompkins Company and was completed in its present form in 1948, with the exception of the installation of the remaining boilers.



Coal storage yard as seen from the roof of the plant. In the far corner is the remotely controlled shifting winch which moves tail block trolley on a monorail.

A.S.M.E. SPRING MEETING

WASHINGTON, D. C., was host to the Fiftieth Spring Meeting of the American Society of Mechanical Engineers on April 12th to 14th. The three-day meeting, held at the Statler Hotel, comprised over twenty technical sessions devoted to papers on fuels, power, gas turbines, heat transfer, instruments, management, machine design, aviation and rockets, in addition to luncheons, social events and several interesting inspections, including a visit to the new Potomac River Generating Station of the Potomac Electric Power Company. Abstracts follow of a few of the papers believed to hold special interest for COMBUSTION readers.

Fly-Ash Collection

Three papers at the first Fuels Session dealt with fly-ash and dust problems in the small plant.

The first of these, by **A. A. Petersen** of Prat-Daniel Corp., called attention to the fly-ash problems resulting from a trend toward legislation for more stringent dust codes. The following tabulation shows the permissible dust concentration as prescribed by several cities.

City	Effective	Gr per cu ft @ 500 F
St. Louis	1940	0.750
Pittsburgh	1941	0.750
Toledo	1946	0.257*
Detroit	1947	0.300
Los Angeles	1947	0.400
Providence	1947	0.257*
Syracuse	1948	0.257*
Pittsburgh	Proposed	0.300
St. Louis	Proposed	0.257*

* Suggested A.S.M.E. Code.

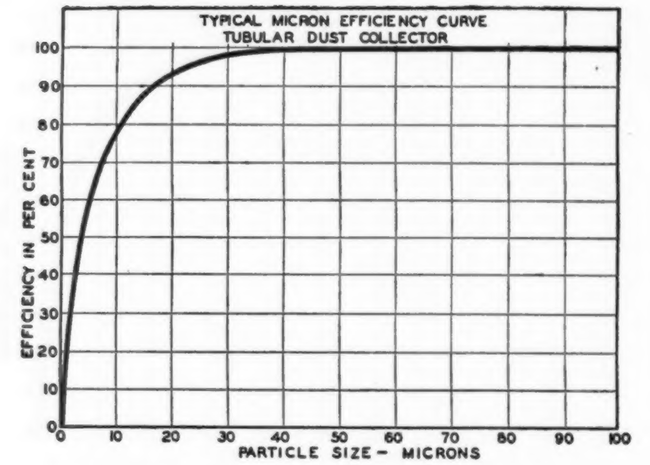
"It is becoming increasingly apparent," said Mr. Petersen, "that proper selection of stoker and furnace, use of coal with characteristics best suited to the particular method of firing, proper and efficient operation of equipment, and settling hoppers are not adequate to prevent a fly-ash nuisance in the light of present-day public thinking, exposed to the crusading influences that are being constantly brought to bear." He then reviewed the various devices available to collect dust, such as settling chambers, impingement or baffle collectors, electrostatic collectors and centrifugal collectors including the large-diameter cyclone, the fan collector and tubular collectors.

The settling chamber has been widely used, is simple, useful and cheap; but in many instances it will not remove sufficient dust to comply with the later codes.

The impingement, or baffle-type, low-draft-loss collector will separate out more dust than a settling chamber and will operate on natural draft. This type serves a useful purpose, but, again, may not always meet some code limits.

The electrostatic collector will meet almost any over-all collection efficiency desired, but because of high initial cost, space and weight, it is not adapted to most small plants. Moreover, most such plants are stoker-fired and emit relatively coarse ash, whereas the electrostatic collector is most effective on the finer dust.

This leaves for consideration by the small plant the centrifugal type of collector in one of three forms of design. The cyclone, the fan collector and the tubular



Micron efficiency curve for tubular dust collector

collector, each of which Mr. Petersen proceeded to describe. A typical micron efficiency curve for a tubular dust collector is here shown from which it will be noted that better than 90 per cent efficiency is attained on micron sizes down to 15 microns, and that up to 94 per cent of stoker size fly ash will be removed.

The second paper on this subject was by **W. L. Prout,** chief engineer of The Green Fuel Economizer Co., who pointed out that since few small plants burn pulverized coal, fly ash is only a minor part of the stack discharge which is likely to consist mostly of cinders from stokers that settle in the vicinity of the plant. Moreover, plants of 500 hp and under, seldom employ air heaters or economizers and usually operate on natural draft, unless the collector requires an induced-draft fan.

Most city ordinances limit the total dust emission, without allowance for variations in particle sizes; hence to meet such codes, cinder and fly ash must be considered of equal importance. An exception is Baltimore which allows 0.75 gr per cu ft total with not over 0.2 gr per cu ft retained on a 325 mesh. While considering these limits too severe, Mr. Prout believed an ordinance of this type to be a more logical method of defining a nuisance and one that would permit more leeway in the selection of collecting equipment.

After reviewing the characteristics of several types of collectors suitable for small stoker-fired installations, he offered the following conclusions as a guide.

1. Some sort of collecting equipment should be provided on all spreader-stoker installations, and on underfeed stokers operating at firing rates above 25 to 30 lb per sq ft per hr.
2. Low-draft-loss collectors will meet existing ordinances on practically any underfeed stoker installation.
3. With spreader-stoker firing, some existing ordinances permit use of low-draft-collectors on any installation; others limit their application to the best designed and best operated plants.
4. If no ordinance exists, high-draft-loss collectors should be used if the dust loading entering the collector exceeds 2 gr per cu ft. With lower dust loadings, low-draft-loss collectors will generally prevent a dust nuisance.
5. If a low-draft-loss collector will not permit the plant to operate on natural draft, a high-draft-loss collector is preferred.
6. With reinjection, two-stage collection is recommended, with reinjection from the first stage only.
7. In small stoker-fired plants, coarse particles or cinders are more of a nuisance than fine particles. It is recommended that this be considered in drafting future smoke ordinances.
8. Designers of small boiler plants are handicapped by lack of information on carryover from stoker-fired boilers, and it is recommended that stoker manufacturers release more such data covering various stoker, boiler and fuel combinations.

H. O. Danz, of American Blower Corp., presented the third paper at this session. He noted that there is no universally satisfactory definition of a dust nuisance, but that in most cases utilities go further than merely complying with city ordinances. More and more industrial plants are installing fly-ash recovery equipment and the smaller plants must follow, although there ordinarily is very little carryover with hand-firing. However, when carrying heavy overloads both hand-firing and underfeed stokers are likely to produce smoke. With spreader stokers 30 to 60 per cent of the discharge is likely to be finer than 100 mesh. It is important to provide sufficient hopper space under the last pass. Mechanical equipment suitable for small plants should catch 60 to 90 per cent of 20-micron ash.

Discussion

Discussion of the three papers called attention to the fact that many small plants are converting to oil; that the A.S.M.E. Code allows a comparatively low efficiency collector in small size to meet the requirements; that the District of Columbia has no dust loading requirements; that in some localities, white fly-ash discharge from stacks is more provocative of complaints than cinders from stokers; and that B.C.I. is now conducting an investigation to collect reliable data on stack discharge from small plants.

Fluid Energy Pulverizer

A fluid energy pulverizer, developed by the Blaw-Knox Company, was described in a paper by **L. D. Bechtel** and **G. M. Croft.** This machine, which was designed especially to handle low-grade coals and coke breeze, operates on the high-velocity jet principle with either steam at 100 psi, 750 F or air as the motivating medium. The raw material is fed by a screw and introduced into the pulverizing chamber by an injection nozzle. Here it is subjected to the action of four high-pressure jets spaced 90 deg around the periphery and near the base of the pulverizer. Pulverization is accomplished by collision and impingement of the fuel particles. The larger particles are recirculated and the final product passes through a classifier at the top.

For coal a fineness of 90 per cent through a 200 mesh is claimed and for some other materials a much finer size. Tests have indicated that optimum grinding efficiency increases with nozzle pressure up to 100 psi

and 750 F, but beyond this, there is no apparent improvement.

A mill having a capacity to pulverize 3000 lb per hr of bituminous coal to a fineness of 90 per cent through a 200 mesh will use 400 cu ft of free air per minute compressed to 100 psi at 70 F total temperature; or the same mill will consume 200 cu ft of free air per minute when compressed to 100 psi and heated to 750 F.

Several commercial installations of the fluid pulverizer are now reported to be operating in industrial plants.

Quick Starts on Large Turbines and Boilers

Messrs. **J. C. Falkner, D. W. Napier** and **C. W. Kellstedt,** of Consolidated Edison Company, New York, reported on the latest developments in the technique for quick starts on large turbines and boilers, which was originally described in a paper at the Semi-Annual Meeting in June 1947 and later before the Metropolitan Section in May 1949.[1]

As stated in the previous papers, the principle of the quick-start procedure consists of admitting steam to the turbine at a temperature equal to or higher than the metal temperature of the heavy section of the machine, the purpose of matching these temperatures being to eliminate or minimize practically all of the thermal shock coincident with the start of a turbine-generator.

Since the first 15-min quick start was made on a 53,000-kw, 1200-psi, 925-F topping turbine at Waterside station in June 1946, more than a thousand such starts, after overnight shutdowns, have been made up to March 15, 1950, on fourteen large topping and condensing units at the Waterside, Sherman Creek, East River and Hudson Ave. Stations of the Company. All of these units are started in 15 min with the exception of No. 4 tandem-compound, 160,000-kw condensing unit at East River Station which is now started in 20 min.

Decision to shorten the rolling period of a unit is not taken arbitrarily. On the contrary, data including the shell metal temperature gradient, expansion, vacuum, and operators' observations on the normal long-roll start are first carefully studied. If there is nothing to show that it would be detrimental to shorten the starting time, instructions are issued to make the next start in 10 to 15 min less. Again, the record of the shorter start is analyzed and a second shortening of the time is made. This procedure is repeated until the starting time is finally reduced to 15 min.

While the common header system lends itself to quick starting by delivering steam that is always hotter than the turbine shells, such is not the case on the unit system where the steam temperature leaving the superheater, after an overnight shutdown, is always lower than desired until sufficient mass gas flow and gas temperature can be attained at the superheater. However, by this summer, the Company will have installed on all its single-boiler, single-turbine topping units, turbine bypasses, so that steam will be introduced into the turbine only when it reaches a temperature 50 to 100 deg hotter than the turbine shell.

The paper pointed out a fallacy in the belief of some operators that little or no metal stress develops in the turbine when it is started immediately after an accidental shutdown; for tests have demonstrated that even after a few minutes shutdown the turbine temperature may be several hundred degrees hotter than the entering steam on restarting. Under this condition, the turbine spindle, with its higher rate of heat transfer, cools off faster than the turbine shell and a possible forward axial rub may result.

Another problem is the starting of boilers and turbines after shutdowns when the boiler pressure has been reduced to zero or a very low value. Such boiler starting is entirely different from that of a boiler which has been bottled up near operating pressure during an overnight shutdown. In the latter case, the boiler is brought in operation only a few minutes longer time than that required for the turbine.

Accordingly, studies were made to determine temperature changes that occur in high-pressure boilers during such cycles by installing thermocouples on No. 90 boiler at Waterside Station, which is designed for 1,000,000 lb per hr at 1800 psi and 950 F. From the data obtained it was observed that during an overnight shutdown, when the drum pressure was allowed to fall 300 psi, a large temperature differential occurred between the top and bottom of the drum metal. On the other hand, in all the tests it was consistently observed that no appreciable drum metal differential was created during the starts of this boiler. It was concluded that the reason for the bottom of the 60-in. drum cooling faster than the top, was the introduction of feedwater, cooler by several hundred degrees than the on-line feed temperature after the mills were cut out, due to loss of heat from the economizer and the bleed heaters.

With the assurance that only minor drum metal temperature differences exist in a normal start, it was decided to quick-start this unit after a three-day outage. The first quick start test was made on February 5, 1950, when the time was reduced from 7 to $3^1/_2$ hr and during which normal firing rate was increased on the basis of raising the drum pressure such as would increase the saturation temperature approximately 150 deg per hour. The drum metal temperature differential did not exceed 35 deg F and superheater metal temperatures did not reach excessive values.

While experience in reducing the starting time of boilers from cold condition has thus far been brief, the authors were of the opinion that such starting can be safely done at a much faster rate than now generally advocated by the boiler manufacturers.

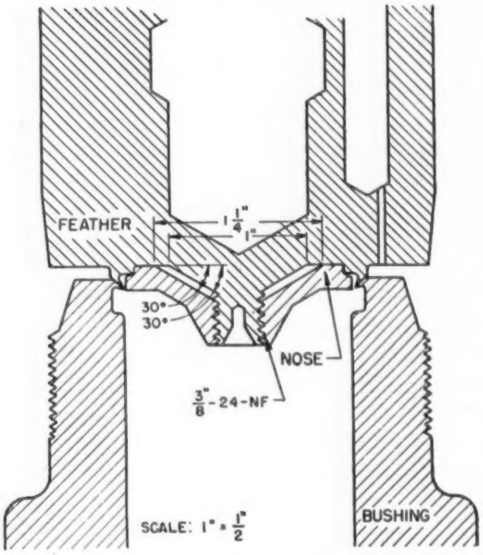
Sealing of High-Pressure Safety Valves

The reason for difficulty in sealing with safety valves, as compared with other types of valves, is that with the former, the seating surfaces are held together only by the difference in loading between the set load of the spring and the operating pressure.

Many factors can contribute to valve leakage, such as distortion of the seating surfaces, dirt or other foreign matter on the seats, or damage caused by grit in the steam. Moreover, when leakage starts, continued operation at normal pressure will result in continual leakage of the valve, which in turn leads to erosion of the seating surfaces. With increasing steam pressures the problem has become more severe.

In view of this situation, a fundamental investigation

[1] See COMBUSTION, August 1947, and June 1949.



Assembly of new safety valve seat design

as to the cause of safety-valve leakage was undertaken, the results of which were reported in a paper by **R. E. Adams,** of Battelle Memorial Institute, and **J. L. Corcoran,** chief engineer of Consolidated Safety Valve Division of Manning, Maxwell & Moore.

This investigation revealed that poor sealing is the result of self-induced growth of tiny initial leaks. Expansion of the leaking steam cools local areas of the valve seat, causing contraction of the seating surfaces in a manner which increases the magnitude of the leak. To combat this, a new design of valve seat, as shown in the accompanying sketch, was developed, incorporating thin flexible seating surfaces. The cooling effects of the leaking steam were thus minimized by providing better heat transfer from the high-temperature steam.

Shock Tests of Austenitic and Ferritic Steel Piping

Thermal shock tests of 6-in. pipe and valve assemblies, representing both austenitic and ferritic steels in 80 and 160 schedules, as carried out at the U.S.N. Engineering Experiment Station, Annapolis, were described in a paper by **W. C. Stewart** and **W. G. Schreitz.** The procedure employed simulated conditions resulting from carryover of boiler feedwater into main steam lines operating at 900 to 2000 psi and 1050 F. Also, cyclic deflection tests were carried out of full-size mock-ups consisting of 160-schedule pipe and valves for simulating expansion bends.

The assemblies were shocked by introducing either 60 or 88 lb of boiler water at the saturation temperature along with the flow of superheated steam, each assembly being subjected to 100 or more shocks. Temperature differentials in the pipe walls showed that the maximum temperature difference between the inside and outside of the wall was obtained for the ferritic steel. Moreover, the maximum temperature difference occurred in a much shorter time with the ferritic steel. However, all four thermal shock specimens withstood 100 or more shocks without failure by rupture.

Fatigue tests at 1100 F showed considerable superiority for the 18–8 Cb pipe material.

Gas Turbines

Among the papers delivered at the two sessions sponsored by the Oil and Gas Power Division, were three on gas turbines, one on practice in Britain and two dealing with development work for the U. S. Navy.

T. W. F. Brown, Research Director of the Parsons & Marine Engineering Turbine Research & Development Association (Pametrada), cited the various government bureaus, research associations and private firms in Britain that are now engaged in research relating to gas turbines or in the actual construction of such units.

Considerable work is in progress on open-cycle gas turbines for marine propulsion, much of which is on Admiralty order. This is as follows.

Firm	Horsepower	Life	Duty
Metro-Vickers	2,500	Short	Naval
Metro-Vickers	4,800	Medium	Naval
English Electric	6,000	Long	Naval
Rolls Royce	6,000	Medium	Naval
Pametrada	15,000	Long	Naval
Pametrada	3,500	Long	Merchant
British Thomson-Houston	1,200	Long	Merchant

In addition to the above, John Brown & Company is constructing a closed-cycle gas turbine set designed for 12,500 kw under license agreement with Escher Wyss of Switzerland.

For merchant marine service, long life at full power is essential, which means a relatively heavy unit operating at about 1250 F in contrast to naval applications where life at full power can be comparatively short, although long life at cruising speed is desirable.

Comparing the steam turbine, the direct-coupled oil engine, a closed- and an open-cycle gas turbine, each of around 7000 hp for marine propulsion, the author listed weights of the main engine units as 404 tons for the diesel, 203 tons for the closed-cycle gas turbine, 178 tons for the open-cycle gas turbine and 236 tons for the steam turbine and boilers.

Mr. Brown was of the opinion that one of the main problems in the application of gas turbines to marine service is ability to burn heavy boiler oil without fouling or corroding the turbine blading or heat-exchanger surfaces. Should the diesel engine be able to burn such oil, it will remain competitive until gas turbines can be produced at reasonable cost. Moreover, it is only when very high temperatures can be employed in the gas turbine by the application of cooling that it will have the field to itself from the standpoint of thermal efficiency.

A report on test experiences with the 3500-hp gas-turbine plant at the U. S. Naval Engineering Experiment Station, Annapolis, was given by **A. C. Skortz** and **F. R. Gessner, Jr.,** both of that laboratory. This covered operational history from December 1944 to December 1948, when the performance tests were completed. During this period the unit operated 3200 hr, was started 357 times and had an availability of 28 per cent. This relatively low availability was due to its having been shut down and partially disassembled for inspection after runs at specified inlet temperatures up to 1500 F.

Of the down time 43 per cent was for scheduled inspections and adjustments, and 57 per cent for repairs.

The principal troubles encountered were failure of three blades of the axial compressor in September 1946, when operating at 1400 F, a burn-through in the combustor of the power turbine in July 1947, and erosion of the first- and second-stage turbine blading, due to metal carryover (18–8) from the combustion chamber, which was observed when down for inspection in March 1948, after a run at 1500 F.

The maximum power obtained from the unit was 2990 hp at 1500 F inlet temperature, under which conditions the fuel consumption was 0.73 lb of diesel oil per horsepower-hour. Thermal efficiency was 17.6 per cent, based on the high heating value of the fuel, or 19.2 per cent when based on the low heating value. The compressor efficiency at rated speed of 5180 rpm and a compression ratio of 4 was 84 per cent.

"The Prospects of Gas Turbines in Naval Applications" was the title of a paper by **Comdr. R. T. Simpson,** U.S.N. and **Comdr. W. T. Sawyer,** U.S.N. Following a brief review of gas-turbine activity within the Bureau of Ships, the authors cited the following requirements of gas turbines for naval applications.

1. Excellent cruising, or light-load full economy plus good fuel economy at higher loads
2. Maneuverability to accommodate rapid load changes, stopping and backing
3. Air economy to keep down the weight of ducts
4. Resistance to shock or other battle damage
5. Economy of strategic materials
6. Reliability
7. Minimum weight
8. Minimum space
9. Accessibility

Since a naval vessel operates for the greater part of its life at a very small proportion of its installed power, the authors suggested an arrangement in which cruising power would be supplied by a steam turbine and booster power for high speed by several gas turbines connected through clutches to the gear train. The steam plant would be designed for economical operation at the speeds for which it alone would be employed, and the gas turbines would be of light weight—about 2 lb per hp in contrast with 16 lb per hp for the steam plant. A net saving of about 28 per cent in total weight would be achieved and the combined fuel economy would at least equal that of comparable steam machinery at all speeds.

Only one boiler per shaft would be required for the steam plant and the gas turbines would be adaptations of the now familiar 500 hr open-cycle aircraft turbo-propeller engine with a turbine inlet temperature of 1900 F. The same oil would be used for both boilers and gas turbines.

Looking to long-range development, the authors believed that consideration should be given to employment of still higher temperatures, of the order of 2500 F, and much higher pressure ratios than those now in use. This would call for concentration on the development of compact, lightweight, highly efficient compressors with the more effective utilization of intercoolers or wet compression. Perhaps the problem of compressor fouling may make it desirable to place greater emphasis on further development of the completely closed cycle.

Facts and Figures

The first gas turbine patent was issued to an Englishman by the name of John Barber in 1791.

●

According to the British Electricity Authority, the present rated electric generating capacity of central stations in that country is in excess of 13,600,000 kw.

●

On a percentage basis, the greatest recent increase in energy consumption has been in the Northwest.

●

Wooden water pipes, joined with iron bands, once served Philadelphians for two hundred years; lately exhumed, they are still in excellent condition.

●

Central station companies in the United States are reported to have invested already between thirty-five and forty million dollars in dust collection equipment.

●

Many long belt conveyors have been used in construction, one of the longest having been a 10-mile belt conveyor system that was employed for the Shasta Dam on the Sacramento River in California. Single belts nearly two miles in length are being used to handle coal in underground mining.

●

When sodium sulfite is applied to boiler water as an oxygen scavenger, it reacts with the free oxygen to form sodium sulfate and thus renders the boiler water non-corrosive, providing the pH is above 8 and the temperature sufficiently high.

●

On the basis of heat input to the steam, at usual boiler efficiencies, the recent boost of 15 cents per barrel in fuel oil price along the Atlantic Seaboard is equivalent to an increase of about 60 cents per ton in the price of coal.

●

The American Petroleum Institute reports proved reserves of crude oil and natural gas in the United States as having reached an all-time high. At the close of 1949, for crude oil and natural gas liquids the estimate was 28.3 billion barrels and 180 trillion cubic feet of natural gas.

The Mercury-Water Binary Cycle

An elementary discussion of the mercury-steam cycle, comparing its thermodynamic features with the Carnot cycle and balancing its advantages against its present limitations.

By LESLIE M. ZOSS
Purdue University, Lafayette, Ind.

USE of water for generation of steam and power has never been completely acceptable to the engineer, although it has been, and still is, the primary fluid. The formula for efficiency of the Carnot cycle, $n = (T_s - T_r)/T_s$, where n is the efficiency, T_s the source temperature and T_r the rejection temperature (absolute), shows that the efficiency is dependent on the temperature only. The efficiency of the cycle then increases as the temperature difference between the source and the receiver increases. Since temperature of the receiver is limited to that of the condensing fluid, the only way to increase the efficiency is to increase the temperature of the source.

It was this reason mainly that led men like W. L. R. Emmet and H. H. Dow to consider the possibilities of another fluid, or the use of two fluids in meeting this problem. Water has been almost without a competitor as the bottom fluid, since it can be expanded efficiently to the temperature set by the condensing water which varies between 40 F and 80 F, depending on the source and the time of year. In the present discussion mercury will be considered as the top fluid, although others such as diphenyl, diphenyloxide, aluminum bromide or zinc ammonium chloride might be used.

In order to analyze the process it will first be necessary to examine a simple system. A simple mercury-vapor system is indicated in Fig. 1. The mercury is vaporized in the mercury boiler at low pressure and passed through a mercury turbine. The condenser for the mercury turbine is also a boiler in that the condensing fluid is water. In the condenser boiler the latent heat of the mercury is transferred to the water, and steam created by this process is passed through superheating coils located in the stack of the mercury boiler and from there to the steam turbine. Condensed mercury is returned to the boiler by gravity feed, eliminating the necessity of a pump, although in some cases pumps have been employed.

The theory behind the mercury-steam cycle can be simply shown by an examination of it on the T-ϕ (temperature-entropy) chart. If we assume adiabatic expansion of the mercury vapor from E to F, no temperature difference between the mercury and the water, isentropic expansion of the saturated steam from point F to G, and that the regenerative cycle has an infinite number of feedwater heaters for the steam cycle, it will appear as shown in Fig. 2. By assuming the regenerative cycle as 100 per cent efficient, the area $BCKB$ is then equal to $GFHG$. That of the actual cycle can then be considered as $KCDEHK$. This area approximates the Carnot cycle area $KD'EHK$ very closely, the only difference being the area $CD'DC$.

Since the heat content of mercury is approximately one-tenth that of water, a fractional part of a pound of steam must be considered if a pound of mercury is used

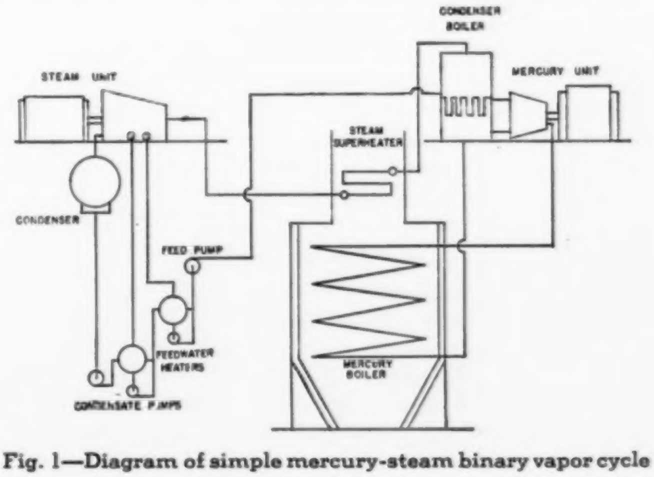


Fig. 1—Diagram of simple mercury-steam binary vapor cycle

in calculating efficiencies. This fractional part is calculated to be 0.12 lb as shown in Fig. 2. Using the previous assumptions, and by taking temperature values from Fig. 2, the efficiency of the cycle may be calculated as follows:

Temperature of mercury in boiler = 910 F
Temperature of mercury and water in the condenser-boiler = 460 F
Temperature of water in condenser = 80 F
Heat input to mercury = $h_{gE} - h_{fC}$ where h_{gE} = enthalpy of saturated vapor at point E and h_{fC} = enthaply of saturated liquid at point C.
Heat input = 149.6 − 16.0 = 133.6 Btu.
Work output = heat input − heat rejected
Heat rejected = T $(\phi_H - \phi_K)$ where T = temperature of water leaving the condenser and ϕ = entropy of respective points.

Points H and K may be used because the regenerative cycle was assumed to be 100 per cent efficient.

Heat rejected 540 (0.178 $-$0.078) = 54 Btu.
Work output = 133.6 $-$54.0 = 79.6 Btu.

$$\text{Efficiency} = \frac{79.6}{133.6} \times 100 = 59.6 \text{ per cent.}$$

$$\text{Carnot cycle efficiency} = \frac{910 - 80}{910 + 460} \times 100 = 60.6 \text{ per cent}$$

The small difference in efficiency between the two cycles, as stated before, is a result of the area $CD'DC$. The efficiency of the steam cycle, under the regenerative cycle assumption would then be

$$n = \frac{460 - 80}{460 + 460} \times 100 = \frac{380}{920} \times 100 = 41.3 \text{ per cent}$$

These values bring to light one of the widest applications of the mercury cycle which can be very effectively used as a topping unit. Because of the high temperatures that can be reached at relatively low pressures, mercury can be used to top any existing steam unit.

Had the mercury cycle been used as a toping unit in the preceding example, the increase in plant efficiency on the basis of the steam cycle would have been 44.3 per cent.

However, under actual conditions the results of the previous calculations could not be obtained, for wise economy would require superheat of the steam and possibly of the mercury in order to protect the turbines from wearing action of the wet vapors.

From a thermodynamic definition of heat alone, it can be seen that in order to condense the mercury vapor and make steam, there must exist a temperature difference between the two fluids in the condenser boiler. It would also be impossible to obtain adiabatic or isentropic expansion. Furthermore, it would be unwise to invest in an unlimited amount of feedwater heaters, as the savings in increased efficiency might never equal the original investment and maintenance costs. It is therefore evident that as the system is put into practice, the area $KCDEHK$ is decreased, thus lowering the efficiency. However, the efficiency will still be above that of the single fluid steam cycle. In a recent article an efficiency record of 37.19 per cent was claimed for a mercury-steam unit (13).[1]

The high temperatures in the mercury-vapor cycle are responsible, along with the properties of mercury, for the increase in efficiency over the steam cycle. In the mercury-vapor cycle these temperatures can be reached without resorting to high pressure. In other words, the temperature limit is not set by pressure, but by the ability of the metals to withstand the temperatures.

Mercury is an element and is stable well above the temperatures that are possible with available materials. The critical temperature is 2240 F. The freezing point is $-$37.97 F, thus eliminating any danger of solidification in the tubes. The specific heat is very small, which results in a steep liquid line on the T-ϕ diagram. The specific volume is small at the condensing temperature so that excessive area of the exhaust passage is not necessary. This quality overcomes the problem of efficient discharge from the last stage. Spouting velocities are low, hence simple turbines at low speeds may be used.

Although mercury has many decided advantages, it has a few major disadvantages that retarded the cycle for many years, the most important of these being the cost of mercury itself. Because of the differences in the latent heat of mercury and water it becomes necessary to circulate six to seven pounds of mercury for every pound of water. That is why a large amount of mercury is needed. Mercury has ranged in price from \$0.50 to \$2.00 per lb, and because such a large quantity is needed it has offset operating savings by increasing the initial cost.

Inasmuch as the initial cost of the mercury unit is high, it has been slow in gaining the position that it

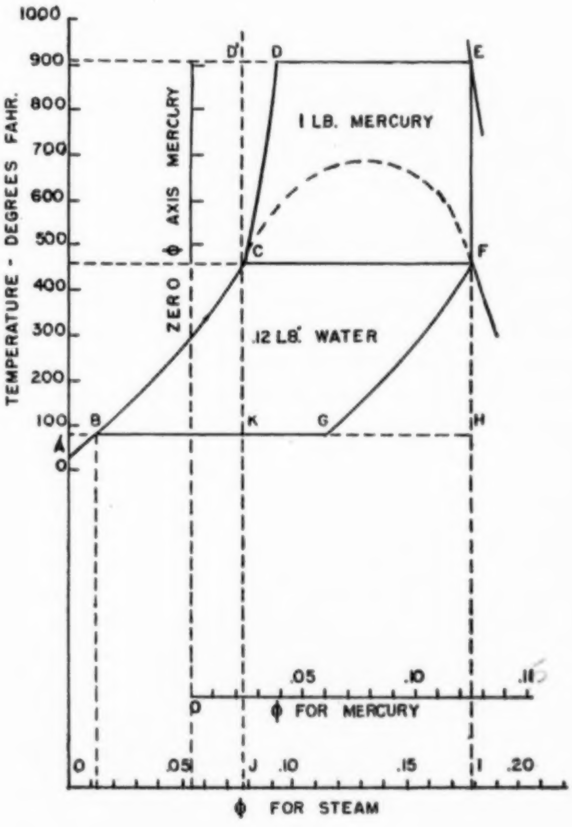


Fig. 2—Binary-vapor cycle on the T-ϕ diagram

otherwise might have attained due to its efficiency possibilities. For some time it was held back because of the problem of heat transfer in the mercury unit. Mercury has a tendency not to wet the surfaces with which it comes into contact. This increases the resistance to heat transfer and therefore a much greater area must be used in order to effect the required heat transfer. However, it is the ideal condition for the turbine, for, as long as the mercury does not wet the turbine blades, wear will be at a minimum. In order to effect the required heat transfer, the porcupine type boiler drum was first used in both the boiler and the condenser. It was found, however, that the mercury did combine with the tubes in large quantities, blocking them and thereby causing overheating and actual damage.

[1] Figures in parentheses refer to references at end of this article.

Due to the efforts of chemists of General Electric Laboratory, it was subsequently found that mercury could be made to wet the tubes and refrain from combining with any of the elements in the tubes by the addition of sodium and titanium into the system. The results were tested in the Kearny plant by General Electric in 1934, at which time only sodium was added to the system. The quantity added was small, being only a few parts in a million. Up to the time the sodium was added, the Kearny plant had been able to carry only a small fraction of rated load, due to the heat transfer difficulties. After the sodium was added it carried full load for three months with no overheating. But examination of the system at the end of this time showed that the tubes were becoming blocked by a mixture of mercury and sodium ferrite caused by the entrance of oxygen into the system. In order for the sodium to work, the system would have to be purged of oxygen. This would have been very difficult, not to mention the expense involved.

Further experimentation showed that by adding small amounts of magnesium and titanium, the same increase in load could be handled as with sodium. With the addition of magnesium and titanium, mercury wet the surface of the boiler. It was therefore no longer necessary to retain the porcupine tube boiler, as enough area to effect the required heat transfer could be obtained from a regular wall tube boiler. The addition of the magnesium and titanium resulted in a harmless dry powder, magnesium oxide, which could easily be removed from the boiler.

Excessive air leakage, which could produce a large amount of magnesium oxide, is blocked out by special carbon-ring liquid-seal packings. A vacuum pump may be used while in operation, although steam-jet air ejectors are used to purge the system for starting. By slightly superheating the saturated mercury vapor, the effect of the wet vapor on the turbine blades can be overcome. The turbine wear and erosion are therefore no greater then ordinary, and long life can be expected.

Along with the cost of mercury are other limitations resulting from its physical or chemical properties. Mercury vapor, unlike water or steam, will tend to search out every weak spot in the system and cause a leak. It is therefore more expensive to build a mercury-vapor plant, for each weld and joint require excellent workmanship and materials. This added cost, among other factors, gives the initial edge to the steam cycle, especially at the present high labor costs. However, due to the improved welding methods and the improvements that will come with experience, the day does not seem far distant when the mercury-vapor plant may be built as cheaply as the steam plant.

Mercury vapor is also poisonous, making it necessary to guard against leaks. At $1.46 per lb these leaks can be very expensive. One of the better systems to detect a mercury vapor leak is to pass the stack gas by an ultraviolet light. Mercury vapor is opaque to the rays and will be detected in quantities as low as one part in 300 million.

Conclusions

It is the author's opinion that the binary-vapor cycle, or the mercury-vapor cycle as discussed in this paper, is one of the most promising. However, development of the binary cycle has been slow and costly, and it will not be widely used unless its economic merit can be proved. With increased coal costs, the cycle is likely to be explored even further, and methods found to place installation and maintenance costs on a par with those of the steam plant. As metals are improved to where they can continuously withstand the high temperatures, the efficiency of the cycle should be increased.

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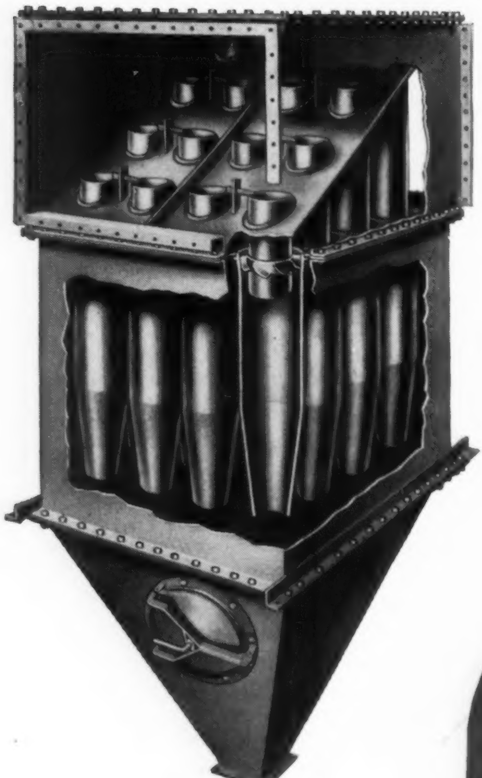
Early Air Pollution History

Air pollution is a problem dating back to the 13th century it was brought out at the recent Air Pollution Conference in Washington. In 1257, Queen Eleanor, wife of Henry the Third, is reported to have left the town of Nottingham, England, because of the smoke from "sea coals." Coal was considered harmful to health, and its use was prohibited in 1273.

Brews, dyers, limeburners and other artisans continued to burn coal. In London, its use increased. Smoke aroused the resentment of the nobility and other dignitaries attending Parliament, and they led the people in demonstrations against the fuel.

In 1306, a royal proclamation was issued, banning its use. A year later, a Commission was appointed and instructed to "inquire of all such who burnt sea coal in the city, or parts adjoining, and to punish them for the first offense with great fines and ransome, and upon the second offense to demolish their furnaces." Caught burning coal in London, one man was reported tried, condemned to death and executed.

Use of the new fuel continued, and in 1661, John Evelyn presented a dissertation to Charles II, pointing out that Londoners "breathe nothing but an impure mist, accompanied by fuliginous and filthy vapor, . . . so that catarrs, phthisicks, coughs, and consumptions, rage more in this one city, than in the whole earth besides." He emphasized the effect of soot and sulfur on buildings, declared that gardens could no longer flourish in London, and advised moving industrial establishments at least six miles down the Thames.



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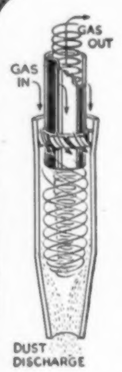

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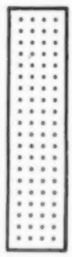
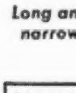
Plant space costs money—so be sure to check space requirements carefully. As shown in the accompanying chart, the MULTICLONE requires less floor space and less cubic space than any other unit of comparable capacity and performance. Translate these savings into today's high costs for plant space and you readily see the great importance of this one MULTICLONE advantage alone!

Make	Relative Space Requirements In Sq. Ft.	In Cu. Ft.
Multiclone	1.0	1.0
Collector A	2.1	1.8
Collector B	5.9	3.2
Collector C	6.8	3.9



Long and narrow



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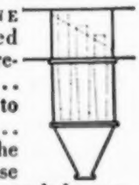
Maximum Adaptability:

In addition to its unusual compactness, the MULTICLONE is also unusually adaptable to various installation requirements. Where head room is low it can be installed with side-inlet side-outlet connections. Where side clearances are restricted, it can be installed with side-inlet top-outlet connections. In addition, without changing capacities, the shape of the unit can be varied—long and narrow, short and wide, or square—to fit restricted spaces . . . and its single-inlet single-outlet duct requirements permit greater flexibility and simpler installation. These savings slice installation costs, space requirements and insulating expense.

Minimum Maintenance:



The MULTICLONE has no high speed moving parts to repair or replace . . . no pads or filters to clean or renew . . . nothing to choke the gas flow or increase draft losses as suspended materials are recovered. MULTICLONE draft losses remain uniformly low *at all times*. Further, the recovered material from an entire bank of tubes is collected in a *single* hopper—far easier to service and maintain than the multiple hoppers of conventional cyclone units.

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Steam Service from Central Stations

By G. D. WINANS

Asst. Supt. of Central Heating, The Detroit Edison Company

The following observations, from a paper before the 1950 Midwest Power Conference, deal with the present status of district heating in this country and discuss various factors that influence the design, extent and economics of such a system. Also included are suggestions for efficient utilization of the service.

THE first recorded attempt to supply heat to several buildings in America, from a central source, was made in 1877 by Birdsill Holly; but the real beginning of the industry occurred in the early part of the present century. At that time there were a large number of small electrical generating stations in operation, most of which discharged to the atmosphere the steam exhausted from their engines. The utilization of this waste heat appeared attractive and many district heating installations were made upon that basis. The advent of the condensing type of electrical generating plant, the hydroelectric plant, and the development of long-distance electrical transmission led to a concentration of electrical generation in large plants with a consequent elimination of electrical generation in numerous smaller units. Many district heating plants were thus forced to resort to the use of live steam direct from the boilers; and having established prices for the heating service based on the assumption that the steam was a by-product of low value, many undertakings were rendered unprofitable until they were permitted to increase their rates considerably.

The financial returns from many of these early projects were unsatisfactory. This was due in some cases to unwise exploitation or to improper management, but in the majority of cases to inadequate selling prices or lack of proper devices for measuring the service.

During the last few years, the position of the district heating industry has improved considerably. This improvement has been due to a greater appreciation on the part of the public of the value of the service and to the increased value or cost of the space occupied by the individual heating plant in large buildings. The increasing congestion of the central districts in large cities has caused the value of space, even in basements, to become very high; and, if this item is taken into account in a comparison of costs, the use of district heating service appears quite favorable.

There are three rather distinct fields in which district heating is employed, each involving different economic and engineering considerations. These are:

(*a*) Service to business districts
(*b*) Service to residence districts
(*c*) Service to industries

Development of district heating service in the business districts of cities is now by far the most important, as to the amount of capital invested and the amount of building space heated. It is a particularly favorable field, first, because of the high density of the load, making it possible to deliver large quantities of steam with a relatively small investment in distribution lines; and, second, because the service is in great demand.

There are a number of district heating systems supplying detached residences and the service is much in demand where it is available. However, there are several obstacles in the way of the general development of this form of district heating. The high cost of the distribution lines and the relatively small quantities of heat which are required in a residence area make the cost of district heating service rather high compared to other methods of automatic heating. There are nevertheless several residential district heating systems in satisfactory operation, particularly in suburbs and small cities, and a few new installations are being made in housing and real estate developments. In most of these cases the district heating system is a part of the real estate or housing development, both physically and financially.

Service to Industries

The supply of steam to industries for manufacturing uses as well as for space heating is a service which gives promise of great future development. Many industries have need for large quantities of heat in manufacturing processes and it often appears economically correct that

their steam requirements, as well as their electrical requirements, be purchased from the public service company. The developments at Rochester, New York, and in Indianapolis are typical illustrations of systems established for this purpose, and are believed to be the forerunner of many enterprises of like nature.

The engineering of district heating may be divided roughly into three phases: Boiler or heating plant, steam distribution systems, and utilization of the steam heating service by the customer.

Steam Heating Plants

Most of the district heating companies are owned by, or are a part of, the electric utility companies serving the areas involved. It is natural, therefore, that the heating plants should follow rather closely the design of the larger electric generating stations. However, because of the low load factor under which heating plants must operate, air preheaters, economizers, and other heating-saving devices are usually omitted. Heating plants, in most cases, are located in or near highly congested and high land value areas where smoke and other dirt factors are a nuisance.

Water Treatment

Boiler-water treatment has been and continues to be one of the most important engineering features of the heating plants, inasmuch as it is impractical to return a large part of the condensate from the customers' buildings. For instance, two of The Detroit Edison Companys' heating plants require from 70 per cent to 85 per cent makeup water, drawn from city water mains. One plant operates on 100 per cent returned condensate, and one plant operates on 100 per cent makeup water. The latest development in boiler-water treatment was fully described in February and March 1950 issues of Combustion ("New Water Treating System Produces CO_2-Free Steam—I and II," by Leo F. Collins and Ernest E. Dubry).

Generating of Electricity

In some plants electric generating units are installed through which some of the steam is passed before being distributed to the heating system. The question as to whether or not generation of the electricity as a byproduct is desirable must be decided in each individual case on the basis of local conditions. The correct answer in any particular case depends largely upon the value of a kilowatt-hour of electricity at the location of the heating plant as compared with the total cost of producing it in the heating plant. The thermal advantage in passing all of the steam through turbine-generators is recognized, but the commercial advantage does not always appear to be favorable. In Detroit, for instance, there is installed sufficient generating capacity to supply the motor-drive auxiliary equipment in the plants, using the exhaust steam to heat the feedwater, delivering any excess electricity to the Company's electrical system. Some small turbine-generators have been installed to deliver electricity solely to the electrical system and to exhaust steam to the steam heating mains. The commercial advantages of combined electricity and steam production are usually more favorable with higher boiler pressures so that present practice may be altered in future installations.

Underground Pipe Construction

There are several types of pipe conduit in common use. The wood casing has been widely used and is satisfactory where the soil is well drained. In the larger cities a more permanent form of construction is employed, such as concrete, vitrified tile, or some of the prefabricated conduits. The conduit should be reasonably waterproof and easily adapted to conditions met within the city streets.

Excavation cost is a major portion of the cost of underground steam mains. It is desirable to keep the excavation depths to a minimum, making the necessary changes in grade of the pipe line to keep near the surface. In Detroit, the approximate cost of underground line construction at the present is:

Normal Pipe Size Inches	Approximate Cost per Foot, (in Detroit)
6	$43
8	46
10	50
12	55
16	65

Our concrete conduit construction dates back as far as 1909. The life of any buried constructon depends greatly upon the soil conditions, and Detroit cannot necessarily be a criterion.

The Detroit steam distribution system contains about $2^1/_2$ miles of horseshoe-shaped tunnels, some of them being as deep as 60 ft., others just under the pavement. It is necessary to ventilate the tunnels by suction fans and, when work is to be done in the tunnels, the nearest manhole cover is opened so that the amount of ventilation in the immediate area is increased. The tunnels are equipped with telephone and lighting systems. It is sometimes desirable to have tunnels in congested downtown districts where it is necessary to install two or more pipes in the same street making it unnecessary to tear up the street either for the original installation or any necessary repairs.

Pipe lines to return the condensed steam from the customers' premises to the heating plants are costly to install and to maintain. Their installation in connection with buried steam mains is seldom justified. Therefore, the condensate from most customers is discharged to the sewers, except in a few special cases.

In the tunnels it is necessary to install condensate lines to handle the drips from the steam mains, since the tunnels are mostly below the sewer lines. The condensate from some of the buildings adjacent to the tunnels is discharged into the tunnel condensate lines and returned to the plant. The total amount of condensate returned from all sources is about 22 per cent.

Utilization

Much time and money have been spent in developing to a high degree the efficiencies of both utility and isolated heating plants. The matter of increasing the efficiency of a plant by a fraction of one per cent is considered important. Very little may be gained however, if, after developing the efficiency of the steam producing plant to such a high degree, the steam is used in the building heating systems in a wasteful manner. Unfortunately, a very large part of the existing buildings of this country

do not follow truly economical practices in their heating operations. The difficulty lies in old and poorly designed heating systems which cannot be operated in an economical manner without extensive alterations, the installation of suitable instruments, automatic temperature control equipment, and an improvement in operating practices.

The district heating business in most cities exists under rather competitive conditions. Many companies feel that from a commercial standpoint, therefore, it is necessary to have a program of assisting the customers to obtain the maximum results from the steam they purchase both for heating and processing. Some companies maintain a staff of engineers and technicians to instruct the customers in the use of their present equipment and advise them of changes which will reduce the amount of steam required and to cooperate with architects and engineers in the design of heating systems for new buildings. Factors influencing the amount of steam used for heating are:

(*a*) The number of degree-days for the area in which a building is located.
(*b*) The size or volume of a building and the type of construction.
(*c*) Hours of occupancy requiring heat.
(*d*) Occupancy or use.
(*e*) Type, design and condition of heating system.
(*f*) Kind of building temperature control.
(*g*) Efficiency of the operating personnel.

For any given building, there is very little that can be done about the first and second items. Proper consideration of the remaining items, however, usually results in important savings in steam consumption.

Studies and experiments have demonstrated that one of the most fruitful methods of conserving heat is to shut off the heating system completely during the non-occupied periods, except as may be necessary to prevent freezing. Separate steam supply lines to those portions of the building, which regularly require long hour heating, pay for themselves in a very short time.

Type, Design and Condition of Heating System

It cannot be said that any one type of building heating system is definitely superior to all other types. For example, in a small building a simple one-pipe heating system, if properly operated, may give as satisfactory results as a more complicated system. In the larger buildings heated by direct radiation, the high vacuum systems seem to produce the most economical results, probably because the steam piping and radiators are maintained at low temperatures and there is less possibility of overheating.

In most cases where heating is accomplished by the circulation of heated air, the economy is good, provided proper consideration is given to the recirculation of the air.

The most important points, with respect to any heating system, are the way that it is designed, installed and maintained. No heating system can operate efficiently unless it will heat the entire building uniformly and will respond rapidly to the changing conditions imposed upon it by outdoor temperature fluctuations. Steam pipe sizes must be adequate and the pipe lines must be properly pitched and drained.

An important major consideration in the design of a building heating system is the zoning and segregation of various parts of the systems where the heating requirements may be dissimilar. Thus, it is usually desirable to provide two or more zones for parts of the building where heating requirements may be different due to exposure or other reasons. In nearly every office building, separate steam supply lines to first floor shops having long-hour heating are desirable.

In very tall buildings, the stack effect must be considered in designing the heating system. Heated air attempts to rise to the tops of these buildings and, to offset this, the openings between floors should be reduced to a minimum and elevator shafts should be enclosed. Despite these efforts to minimize the stack effect, there are instances on record where it was necessary to increase the amount of radiator surface for the first few floors of tall buildings as much as 40 per cent in order to produce comfortable conditions.

One of the most common sources of waste is the overheating of buildings, and much of the work involving the economical use of steam is in connection with building temperature controls. Experience indicates that from 10 to 25 per cent can be expected as a savings by the installation of control equipment. In many cases the overall comfort of the building is improved by the installation of temperature control.

There are many types of temperature control systems ranging from simple thermostats to automatic cycling controls and differential pressure control systems. The simple thermostat systems cost the least while the pressure-differential systems are the most expensive to install. Cost of the control must be balanced against the savings in steam consumption which can reasonably be expected.

Radiator orifices are frequently used in connection with the control of two-pipe heating systems. With orifices in the radiators, the entire supply line fills with steam rapidly, and the radiators at the end of the system are supplied with steam at approximately the same time as those close to the source of supply. If radiators are oversized, the orifices will tend to prevent overheating in that particular section. However, orifices will not increase the heating output of radiators.

In general, the heating systems of buildings using temperature controls have performed acceptably but a considerable number of operating difficulties have been encountered. Some of these difficulties are caused by shortcomings of the heating systems rather than by the controls. Few have been caused by mechanical defects of the control equipment. The majority of difficulties, however, are caused by failure of the building operators to understand and appreciate the equipment itself. This is largely a matter of education and can be corrected only by continual effort.

The efficiency of the building operating personnel frequently has more influence on the economical use of steam than any other single item. This is largely a matter of education of the building management as well as their operating staff. In many cases the building management, in an effort to minimize labor costs, employs unskilled labor to operate and maintain their mechanical equipment. Under these circumstances, waste is inevitable. Those charged with the actual operation of heating systems using purchased steam are usually quite cooperative. They appreciate greatly the

absence of boilers, coal, ashes, labor problems and their accompanying costs.

Steam Compressors

Many companies distribute steam at medium or low pressure. Although the normal supply pressure is sufficient for nearly every requirement of a customer, there are a few uses for which higher pressure (50 to 100 psi) is desirable, such as in some clothes-pressing machines and certain laundry apparatus which have been designed for high pressures where a high temperature is helpful. These uses require relatively small quantities of steam. The cost of installing a parallel network of high-pressure mains to supply these small amounts of steam would be very high when compared to the steam revenue available. Therefore, in some cases customers have installed motor-driven compressors, which take steam at the supply pressure and compress it to the pressures desired for their use. These are ordinary reciprocating air compressors modified by using corrosion-resistant metals in cylinder liners, valve assemblies, and piston rods. The water jacket is filled with insulating material. The power required to compress steam from 30 to 75 psi is about 30 kwhr per thousand pounds of steam. There are twenty-eight of these steam compressors in use in Detroit.

Air Conditioning

Steam for air conditioning has been used very successfully for several years where pressures of 100 to 200 psi were available. It is used to drive centrifugal machines or, directly, in ejector-type machines. Recently, the absorption cycle of refrigeration has been applied to air-conditioning units using water as a refrigerant and some salt solution, such as lithium bromide, as an absorber. These machine will operate on steam pressures from 0 to 15 psi.

Conclusions

The engineering features of the district heating industry, as it concerns steam generating plants, will probably continue to follow along the lines of the large electric generating plants. If coal prices increase, or even stay where they are, more heat saving devices, such as air preheaters and economizers, may be justified. Boilers will be equipped to burn poorer grades of coal without dust and dirt.

There will undoubtedly be more combinations in which electric plants will deliver steam to steam distribution systems.

New materials, particularly new insulation and new metals, will be factors in lengthening the life and reducing the heat loss of the steam main conduits.

Customers' economical use of the service will be improved through wider use of control equipment and the appreciation of good heating service.

Steam heating service, where it is available, has been well accepted. In many cities, 90 to 100 per cent of the available business is served and boilers are not being installed in the new buildings.

Many utility companies have sold out their entire steam heating capacity and are unable to take on additional new customers. Some have installed, and others are installing, additional boiler plant and distribution system capacity.

Properties of Metals at Elevated Temperatures—II

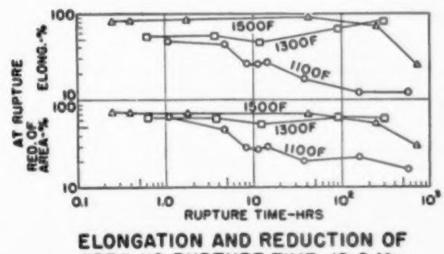
By G. V. SMITH

Research Metallurgist, U. S. Steel Corporation

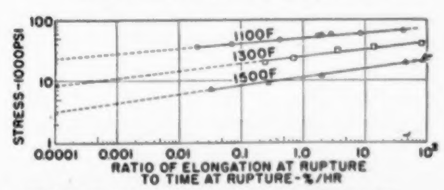
Part II considers effects of nonconstant stress and temperature, metallurgical variables, microstructural and surface changes, and scaling and corrosion. All of these factors are of interest in considering the use of metals for power generation at higher steam temperatures. Part I appeared in the April issue.

We have not yet considered in this discussion the total deformation at rupture in creep-to-rupture tests. This is a matter of considerable interest even though, just as room temperature, we cannot directly employ ductility in design formulas. The variation of elongation and reduction of area at rupture of 18 Cr–8 Ni–Mo stainless steel, as with most other metals, is rather erratic, although showing a general tendency for less ductility with increasing time to failure. As much as one might wish to know how much ductility could be anticipated at fracture in say 20 years, he would not wish to extrapolate the data.

We have recently discovered a means which does appear to be suitable for making such predictions and which we have found to apply in all instances that we have examined. If one takes the ratio of the elongation or reduction of area, to the time for rupture, obtaining thus an average rate of deformation, he finds that this ratio plots linearly against stress on log-log coordinates. The linear relation is suited to extrapolation and permits the estimation of deformation at rupture. One simply determines from the plot of stress versus rupture time, the stress to cause rupture in the time interval of interest, then determines the corresponding average rate of extension, which when multiplied by the time to rupture gives the extension at fracture.



ELONGATION AND REDUCTION OF AREA VS RUPTURE TIME; 18-8-Mo



STRESS VS RATIO OF ELONGATION AT RUPTURE TO TIME AT RUPTURE; 18-8-Mo

Effects of Non-Constant Stress and Temperature

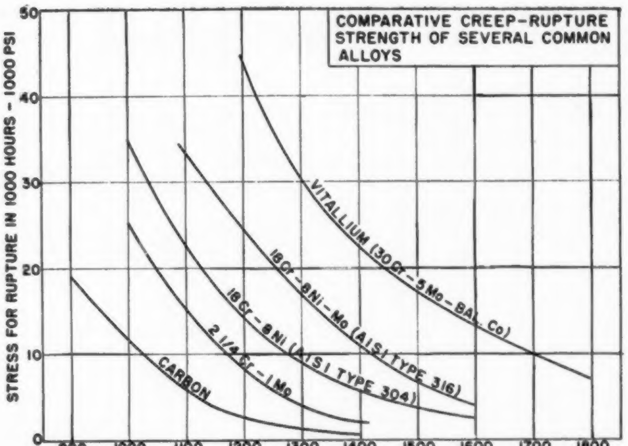
In the foregoing discussion, we have considered the various characteristics of creep phenomena which are of interest in design for service at elevated temperature. The discussion has been in terms of the laboratory creep test carried out under ideal conditions of constant temperature and load and generally under uniaxial tension. In service, temperature and load are often not constant and stressing is multiaxial. Moreover, dynamic or fatigue stressing is often encountered. The application of laboratory test data to design, though difficult enough at ordinary temperature, is especially so at elevated temperatures.

Creep under multiaxial stresses has been studied by a number of investigators, whose results indicate that the shear-strain energy theory, which has been found to describe successfully the plastic flow of isotropic metals at ordinary temperature, may be similarly applied to creep flow.

The effect of non-constancy of temperature and stress has not been studied in any great detail but in recent years interest has developed in this aspect of the problem, and experimental data are now becoming available. The effect of cycling may be expected to depend upon the material and the specific variation. The few data that are available on the effect of cycling temperature suggest that it may be rather pronounced at relatively high temperatures (perhaps above 1500 F for austenitic steels). More data are required.

It has often been suggested that the endurance or fatigue limit of metals at elevated temperatures is less than the creep strength. Further, that if the design stress does not exceed the creep strength, there is no possibility of fatigue failure. This, of course, is an oversimplification and is being increasingly recognized as such. Moreover, failures which are unquestionably of fatigue nature have been observed in elevated temperature service. The oversimplification of the problem is no doubt attributable to ignoring at least two important considerations: (1) the endurance limit can be radically lowered by stress concentrations such as notches, abrupt changes in cross-section and the like; (2) the dynamic stress may be, and frequently is, not completely reversed

* A talk before Process and Metals Division, Metropolitan Section ASME, March 7, 1950.



but is superimposed upon a steady stress. In this latter case the problem of design is especially complex, for the steady stress may be sufficient to cause creep at the same time that the dynamic stress is causing fatigue damage, giving rise to what might perhaps be called a creep-fatigue failure, showing characteristics of both phenomena. Regrettably, few fatigue tests have been made at elevated temperature under other than completely reversed cycles of stress. Fortunately, interest is developing (in recent years) in this long-neglected aspect of the use of metals at elevated temperatures.

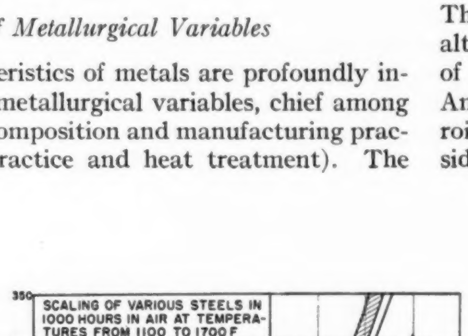
Effects of Metallurgical Variables

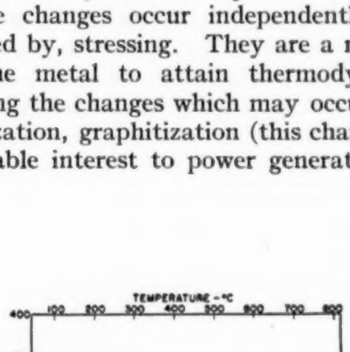
The creep characteristics of metals are profoundly influenced by various metallurgical variables, chief among which are chemical composition and manufacturing practices (deoxidation practice and heat treatment). The most important of these variables is, of course, chemical composition. The temperature variation of the 1000-hour rupture strength of several common steels is shown graphically in comparison with one of the strongest of the so-called "super alloys" developed for gas turbine, jet aircraft and similar applications. By variation in manufacturing practices, such as melting, deoxidation and heat treating processes, the strength of any one alloy can be radically altered. The superalloys, which have been developed largely during the last decade, have become of considerable importance. At 1200 F they are about 3 times as strong and at 1500 F about 6 times as strong as ordinary stainless steel. The advantage of the superalloys can also be expressed in terms of temperature, since a number of them have the same strength at 1500 F as do the stainless steels at 1100–1200 F. They permit an increase in the working temperature of 300–400 deg. F.

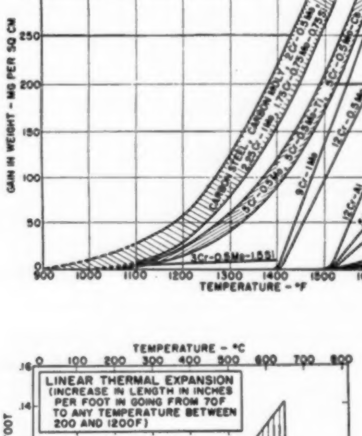
Microstructural and Surface Changes

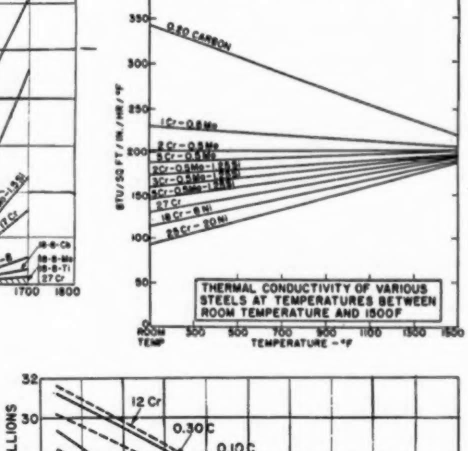
Two other broad aspects of the behavior of metals at elevated temperature should be mentioned, namely the changes in microstructure which bring about changes in strength with time at temperature, and scaling or other corrosive attack of the metal in the environment to which it is subjected.

A number of changes in microstructure may occur in metals merely as a consequence of time at temperature. These changes occur independently of, but may be altered by, stressing. They are a result of the striving of the metal to attain thermodynamic equilibrium. Among the changes which may occur are carbide spheroidization, graphitization (this change has been of considerable interest to power generating engineers in re-









cent years), allotropic transformations, strain-aging, and precipitation processes of one kind or another.

The microstructural changes which occur in a metal during service at elevated temperature cause changes in properties, not only at the temperature of service but at other temperatures as well. Thus, the alloy changes continuously during service; it may become weaker or stronger, tougher or more brittle, depending upon the specific changes which occur.

Scaling or Other Corrosive Attack

The effect of scaling or other corrosive attack is to reduce the effective cross-sectional area of the metal, or, when the attack is localized, to cause stress concentrations. The comparative scaling resistance of various commercially used steels is illustrated by the curves on the preceding page.

The most important alloying element for improvement of the scaling resistance of steel for service at elevated temperatures is chromium. The addition of this element results in the formation of a so-called protective oxide, which retards further scaling. Other alloying elements such as silicon and aluminum act similarly, but can be used only in limited amount owing to adverse effects on mechanical properties.

Miscellaneous Physical Properties

Various other properties are of interest in design for elevated temperature service, although these are not generally controlling factors. Among such properties are thermal conductivity and expansivity and the elastic moduli.

The temperature variation of thermal conductivity of a number of ferrous alloys is shown graphically. It is to be noted that the wide differences in thermal conductivity tend to diminish with increasing temperature.

Length changes which result when various ferrous alloys are heated are also illustrated. It will be noted that the austenitic (18 Cr–8 Ni type) steels undergo appreciably greater length changes than the ferritic steels.

Temperature variation of tensile elastic modulus of several alloys is shown. A general downward trend of modulus is to be noted as the temperature is increased.

Summary

In this brief consideration of the properties of metals at elevated temperature an attempt has been made to furnish a broad overall view of the problem. Much of the paper was devoted to considering creep phenomena. While other properties are of interest, they are generally subordinate, although at high temperatures sealing resistance may be the limiting factor. The intention has been to show that because deformation continues to occur with time in service at elevated temperature, with the end result of fracture, logic demands that economical design be predicated on a limited life rather than an unlimited one. Within this planned life interval, the stress must be so chosen that firstly a maximum permissible deformation is not exceeded and secondly fracture does not occur.

It has also been pointed out and should be emphasized that the translation of laboratory data to actual service is an especially complex problem. However, as more data regarding service behavior become available, solutions are being found.

A.I.E.E. National Power Conference

FEATURED at the first National Power Conference, sponsored by the American Institute of Electrical Engineers and held in Pittsburgh, Pa., on April 19 and 20, with an attendance of more than 300 engineers, were a number of technical papers covering aspects of utility system planning, central station reserves, and maintenance scheduling. There were also luncheon addresses on air pollution problems by T. E. Purcell of Duquesne Light Co., and trends in power by A. C. Monteith of Westinghouse Electric Corp.

System Capacity Requirements

In a paper entitled "Elements of System Capacity Requirements," **C. W. Watchorn** of the Pennsylvania Water & Power Co., advocated the use of simple arithmetic methods to compute generating system reserves, using the familiar elementary probability theory. Results obtained by this method can provide an important guide to system planning and may be used to demonstrate the need for reserve and standby capacity of a utility system. In making use of these techniques, it should be apparent that specific problems are peculiar to individual systems and that there may be danger in attempting to generalize results too widely. Probability also serves as a means of calculating possible future additions to system capacity.

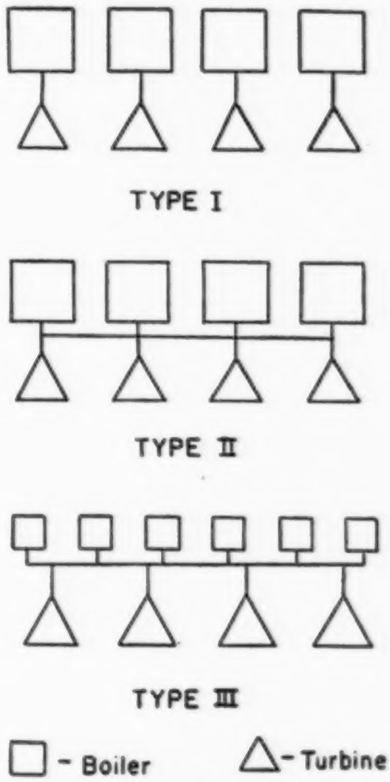
Discussion

This paper brought forth considerable discussion which indicated some contrasting views of the feasibility of applying probability techniques to utility system planning. One engineer pointed out that probability, for reasons which should be obvious, is more reliable when applied to larger systems than to small or relatively isolated utilities. Several others pointed out the important influence of electrical interconnection in considering system reserve requirements. Transmission bottlenecks are among the factors that should be considered in this regard, as well as the effect of interconnection in permitting a reduction in necessary reserve. It was mentioned that investments in strengthening such interconnections may influence the justification for single boiler-turbine-generator arrangements because the electrical interconnections may be carried on with investments that may be less costly than the cross-connection of boiler and feedwater systems in the power plant itself.

Unit-Type Generating Stations

W. J. Lyman, C. E. Mullan and **R. M. Buchanan** of Duquesne Light Co. presented a paper entitled "Economic Evaluation of Unit-Type Generating Stations." One of the more important factors to be considered and evaluated in making a decision as to whether or not the unit-type installation is economical and desirable is the installation cost or investment. The elimination of cross-connections and the accompanying costly valve equipment, together with the lower cost per kilowatt of large boilers as compared to small boilers, results in the lower cost per kilowatt of the unit boiler-turbine-generator construction. Another influencing factor is the effect on reserve capacity requirements; it is generally recognized that unit construction, by comparison with header-type construction, requires a somewhat greater reserve to supply equivalent reliability.

By comparing the savings in installation cost made possible by unit construction with a general evaluation of increased reserve capacity requirement of the unit system, the authors attempted to show how these particular factors may affect a final decision on the basic type of generating station to be constructed. For the purpose of comparison, it is assumed that total boiler capacity is equivalent to total turbine capacity. It is recognized that additional steaming capacity may be advisable under certain circumstances but that can be taken care of in an independent study. Certain published operating data indicate that failure rates on modern turbines and boilers are substantially equivalent; from a reserve viewpoint, this means that it might be just as logical to provide additional turbine capacity as to provide additional boiler capacity.



Station layouts

As an aid to comparison, three different types of station layouts may be considered, representing the unit system, cross-connection, and cross-connection plus a greater number of boilers than turbines. The addition

of new units larger than those existing on a system is highly influential in determining total system reserve requirements. Older and smaller units have less effect on reserve, and the theoretical reserve requirements for the three types of stations are greatest in the earlier years of their operation. With system growth which often follows a pattern of increasing unit sizes, the effect on overall system reserve requirements is to lessen the importance of installing one type in preference to the others.

When the use of unit-type generating stations is accompanied by an increase in installed capacity because of reserve requirements, it would seem desirable that this additional capacity be credited with the savings resulting from its operation. Since this reserve would ordinarily be in the form of newest equipment and would replace less efficient machines, it should result in an operating saving in the form of lower fuel cost and perhaps lower labor cost. The authors made the following statement:

"On one system in the bituminous coal region . . ., economic studies of this fact have shown that after taking into consideration the effects of taxes, the operating savings will cover about 60 per cent of the fixed charges on the additional capacity, including both interest and depreciation."

The authors pointed out that in the cross-connected plants, as shown in types II and III, an extra investment is required for the first unit and full use of this investment may not be realized until the plant is completed, which may be a period of possibly 10 years. Included in this extra investment is the additional space for the steam and boiler feed ties. This investment increases rapidly with unit size and elevated steam temperatures and pressures. A supplemental advantage of the unit system is the possibility of changing the steam cycle from unit to unit, instead of being restricted by the conditions of the first installation as is the case with cross-connection.

The authors concluded that on the basis of their studies, investment savings of approximately 4 per cent were made possible by a unit boiler-turbine-generator design, and that these savings more than offset the smaller reserve requirement of the cross-connected, header-type station.

Discussion

It was brought out in a discussion period, that reheat might have been considered in the evaluation of the unit-type station and might have been shown to provide an additional return on the added investment. The opinion also was expressed that the availability of high-pressure units will approach that of the lower pressure units for which longer operating experience has been had. It was also pointed out that interconnection capacity costs on the order of one-quarter as much as power generation capacity, and this is a factor which should be seriously considered in evaluating the economic effect of a unit boiler-turbine-generator installation upon reserve capacity.

Station Costs Survey

A. E. Knowlton of *Electrical World*, speaking on "Trend of Post-war Generation Costs," indicated that electric production costs are at about the same level as for pre-war plants. Unit costs for fuel, manpower, building construction and electrical and mechanical equipment have all risen sharply since the end of the war. However, skillful design has been a means of holding down the overall kilowatt-hour cost. In general, it can be said that plants using natural gas for fuel have definitely lower cost than those burning coal.

Power plant building outlay varies widely in the total amount per kilowatt. It ranges from an almost negligible amount for outdoor or semi-outdoor plants to as much as 38 per cent for some enclosed coal burning central stations. Reduction in building cost, in some instances, has been achieved by avoiding brick construction and substituting light weight exterior wall panels and by simplifying plant layouts and using a higher degree of centralized control. In addition, the use of 3600-rpm turbines and steam cycles employing extremely high pressures and temperatures has contributed to reduction of building costs.

Air Pollution

The crux of the air pollution problem, according to **T. E. Purcell** of Duquesne Light Company, the luncheon speaker, is the degree of air cleanliness communities can afford. Economic considerations are of primary importance, and some satisfactory compromise between ideal conditions and those which are economically justifiable must be found.

Mr. Purcell strongly advocated local air pollution control and as contrasted to state-wide or national control. Air pollution is largely an engineering problem and may well be considered a part of the engineer's civic responsibility. Opportunities exist in many areas for engineers to make a real contribution in minimizing the effects of air pollution in their communities.

Maintenance Scheduling

Some relatively unpublicized aspects of power plant practice were discussed in a paper entitled "Maintenance and Overhaul Scheduling" by **W. C. Bryson** of Duquesne Light Company. Changes in seasonal load shapes have reduced the spread between capacity and load during periods when heavy maintenance programs formerly were carried out. Added to this is the fact that many systems have not yet achieved their reserve normalcy, and to meet these problems it is desirable to cut maintenance time as much as possible.

A well-coordinated plan is an aid in scheduling maintenance to take maximum advantage of available outage time. Other important items relating to a coordination are the availability of repair parts, arrangement of manpower schedules and close supervison of necessary work. It is necessary to avoid simultaneous outage of large units and to maintain reasonable reserves during the maintenance period. Consideration should also be given to the state of interconnected reserves during periods of major maintenance projects.

Traditionally on many systems, maintenance outages take place between April and October, because at this time seasonal load drops generally are in excess of loss in effective capacity due to higher river water temperatures. Since the war, the difference in load peak between the winter and summer seasons has been greatly reduced, in large measure due to widespread installa-

tion of air conditioning. This has had a great effect on maintenance scheduling, for new ways must be found to offset this load condition or additional reserves must be installed.

In planning maintenance schedules, advantage may be taken of the most expeditious work periods, a factor which can be related to the general trend in system loads. With the shortening of the summer gap, indications are that the early spring months provide the best period for undertaking maintenance work. Another factor which may aid in providing reserve for maintenance of large units is the coordination of vacation periods of utility system customers. As an example, on group customer vacations the Duquesne Light Company provided as much as 50,000 kw for a two-week period over the July 4th holiday.

By reducing outage time for overhauling major units to a minimum, best advantage can be taken of available system reserves. At the same time, savings in operating economically can be achieved, since outage of the more efficient system units usually result in load transfer to units of less efficiency, thereby causing a loss in operating economically.

Extension of time intervals between overhauls is another factor in maintenance scheduling. Improvements in design have contributed materially to longer operation without inspection.

Mr. Bryson concluded by stating that systematic scheduling and maintenance planning aid in performing overhauling economically and effectively. Reduction of overhaul time and increasing service hours between overhauls, serve to reduce maintenance expenditures. Each system should study, develop and adopt the best practices for maintaining and overhauling major units.

Central Station Efficiency Control

A method of removing conjecture about station performance was proposed by **B. G. A. Skrotzki** of *Power* in a paper entitled "Steam-Electric Station Efficiency Control." When unexpected changes in monthly heat rate of a station take place, it is natural that those responsible for operation are concerned with the reasonableness of the result and the question of whether individual equipment has performed satisfactorily under the circumstances. A rigid form of analysis is required to determine the exact effect of each factor on the station heat rate. The method under discussion tells the operators whether or not equipment performs satisfactorily and shows clearly what factors cause unexpected variations in performance.

When this method of analysis is carried out, it is necessary to compare expected performance with actual performance. Close agreement indicates that the equipment is in satisfactory operating condition. If the heat rate is higher, maladjustments in the station cycle are indicated; if it is lower, there is a mathematical error in the computation of either the actual or expected heat rates.

By the magnitude of the deviation from expected performance, the operator can either be assured that his equipment is in order or be given reason to investigate the need for repairs. An index method may be used to establish a base heat rate for a station, which is a theoretical value that cannot be realized in practice. The plan of analysis is to change each of the operating conditions, one by one, from the standard (which is based upon the base heat rate) to the actual heat rate determined on the record of monthly operation. The difference in the two station heat rates is then a measure or index of the effect of that operating factor on the overall station heat rate under consideration.

This form of efficiency control has proved a very illuminating tool in station operation. It prevents chasing up "blind alleys" in which unexpected changes are attributed to but one factor. The true cause of variation in station heat rate generally involves several unrelated factors. Mr. Skrotzki estimated that, once the basic performance data have been prepared, it takes about three man-days per month to collect and classify log sheet data and figure the complete station heat-rate analysis in accordance with the proposed method.

A.I.E.E. National Power Conference

FEATURED at the first National Power Conference, sponsored by the American Institute of Electrical Engineers and held in Pittsburgh, Pa., on April 19 and 20, with an attendance of more than 300 engineers, were a number of technical papers covering aspects of utility system planning, central station reserves, and maintenance scheduling. There were also luncheon addresses on air pollution problems by T. E. Purcell of Duquesne Light Co., and trends in power by A. C. Monteith of Westinghouse Electric Corp.

System Capacity Requirements

In a paper entitled "Elements of System Capacity Requirements," **C. W. Watchorn** of the Pennsylvania Water & Power Co., advocated the use of simple arithmetic methods to compute generating system reserves, using the familiar elementary probability theory. Results obtained by this method can provide an important guide to system planning and may be used to demonstrate the need for reserve and standby capacity of a utility system. In making use of these techniques, it should be apparent that specific problems are peculiar to individual systems and that there may be danger in attempting to generalize results too widely. Probability also serves as a means of calculating possible future additions to system capacity.

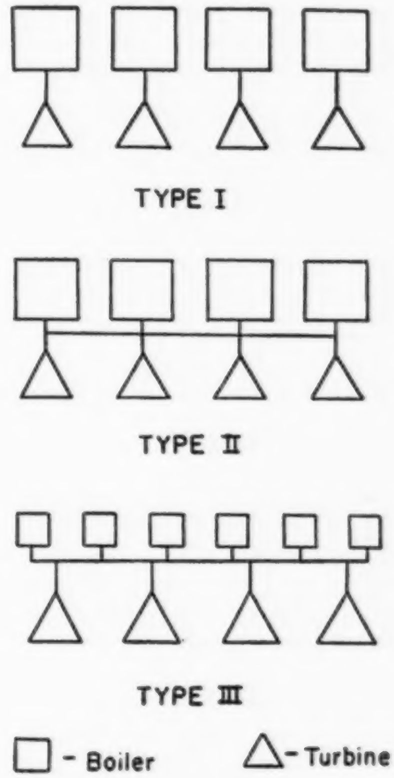
Discussion

This paper brought forth considerable discussion which indicated some contrasting views of the feasibility of applying probability techniques to utility system planning. One engineer pointed out that probability, for reasons which should be obvious, is more reliable when applied to larger systems than to small or relatively isolated utilities. Several others pointed out the important influence of electrical interconnection in considering system reserve requirements. Transmission bottlenecks are among the factors that should be considered in this regard, as well as the effect of interconnection in permitting a reduction in necessary reserve. It was mentioned that investments in strengthening such interconnections may influence the justification for single boiler-turbine-generator arrangements because the electrical interconnections may be carried on with investments that may be less costly than the cross-connection of boiler and feedwater systems in the power plant itself.

Unit-Type Generating Stations

W. J. Lyman, C. E. Mullan and **R. M. Buchanan** of Duquesne Light Co. presented a paper entitled "Economic Evaluation of Unit-Type Generating Stations." One of the more important factors to be considered and evaluated in making a decision as to whether or not the unit-type installation is economical and desirable is the installation cost or investment. The elimination of cross-connections and the accompanying costly valve equipment, together with the lower cost per kilowatt of large boilers as compared to small boilers, results in the lower cost per kilowatt of the unit boiler-turbine-generator construction. Another influencing factor is the effect on reserve capacity requirements; it is generally recognized that unit construction, by comparison with header-type construction, requires a somewhat greater reserve to supply equivalent reliability.

By comparing the savings in installation cost made possible by unit construction with a general evaluation of increased reserve capacity requirement of the unit system, the authors attempted to show how these particular factors may affect a final decision on the basic type of generating station to be constructed. For the purpose of comparison, it is assumed that total boiler capacity is equivalent to total turbine capacity. It is recognized that additional steaming capacity may be advisable under certain circumstances but that can be taken care of in an independent study. Certain published operating data indicate that failure rates on modern turbines and boilers are substantially equivalent; from a reserve viewpoint, this means that it might be just as logical to provide additional turbine capacity as to provide additional boiler capacity.



Station layouts

As an aid to comparison, three different types of station layouts may be considered, representing the unit system, cross-connection, and cross-connection plus a greater number of boilers than turbines. The addition

of new units larger than those existing on a system is highly influential in determining total system reserve requirements. Older and smaller units have less effect on reserve, and the theoretical reserve requirements for the three types of stations are greatest in the earlier years of their operation. With system growth which often follows a pattern of increasing unit sizes, the effect on overall system reserve requirements is to lessen the importance of installing one type in preference to the others.

When the use of unit-type generating stations is accompanied by an increase in installed capacity because of reserve requirements, it would seem desirable that this additional capacity be credited with the savings resulting from its operation. Since this reserve would ordinarily be in the form of newest equipment and would replace less efficient machines, it should result in an operating saving in the form of lower fuel cost and perhaps lower labor cost. The authors made the following statement:

"On one system in the bituminous coal region . . ., economic studies of this fact have shown that after taking into consideration the effects of taxes, the operating savings will cover about 60 per cent of the fixed charges on the additional capacity, including both interest and depreciation."

The authors pointed out that in the cross-connected plants, as shown in types II and III, an extra investment is required for the first unit and full use of this investment may not be realized until the plant is completed, which may be a period of possibly 10 years. Included in this extra investment is the additional space for the steam and boiler feed ties. This investment increases rapidly with unit size and elevated steam temperatures and pressures. A supplemental advantage of the unit system is the possibility of changing the steam cycle from unit to unit, instead of being restricted by the conditions of the first installation as is the case with cross-connection.

The authors concluded that on the basis of their studies, investment savings of approximately 4 per cent were made possible by a unit boiler-turbine-generator design, and that these savings more than offset the smaller reserve requirement of the cross-connected, header-type station.

Discussion

It was brought out in a discussion period, that reheat might have been considered in the evaluation of the unit-type station and might have been shown to provide an additional return on the added investment. The opinion also was expressed that the availability of high-pressure units will approach that of the lower pressure units for which longer operating experience has been had. It was also pointed out that interconnection capacity costs on the order of one-quarter as much as power generation capacity, and this is a factor which should be seriously considered in evaluating the economic effect of a unit boiler-turbine-generator installation upon reserve capacity.

Station Costs Survey

A. E. Knowlton of *Electrical World*, speaking on "Trend of Post-war Generation Costs," indicated that electric production costs are at about the same level as for pre-war plants. Unit costs for fuel, manpower, building construction and electrical and mechanical equipment have all risen sharply since the end of the war. However, skillful design has been a means of holding down the overall kilowatt-hour cost. In general, it can be said that plants using natural gas for fuel have definitely lower cost than those burning coal.

Power plant building outlay varies widely in the total amount per kilowatt. It ranges from an almost negligible amount for outdoor or semi-outdoor plants to as much as 38 per cent for some enclosed coal burning central stations. Reduction in building cost, in some instances, has been achieved by avoiding brick construction and substituting light weight exterior wall panels and by simplifying plant layouts and using a higher degree of centralized control. In addition, the use of 3600-rpm turbines and steam cycles employing extremely high pressures and temperatures has contributed to reduction of building costs.

Air Pollution

The crux of the air pollution problem, according to **T. E. Purcell** of Duquesne Light Company, the luncheon speaker, is the degree of air cleanliness communities can afford. Economic considerations are of primary importance, and some satisfactory compromise between ideal conditions and those which are economically justifiable must be found.

Mr. Purcell strongly advocated local air pollution control and as contrasted to state-wide or national control. Air pollution is largely an engineering problem and may well be considered a part of the engineer's civic responsibility. Opportunities exist in many areas for engineers to make a real contribution in minimizing the effects of air pollution in their communities.

Maintenance Scheduling

Some relatively unpublicized aspects of power plant practice were discussed in a paper entitled "Maintenance and Overhaul Scheduling" by **W. C. Bryson** of Duquesne Light Company. Changes in seasonal load shapes have reduced the spread between capacity and load during periods when heavy maintenance programs formerly were carried out. Added to this is the fact that many systems have not yet achieved their reserve normalcy, and to meet these problems it is desirable to cut maintenance time as much as possible.

A well-coordinated plan is an aid in scheduling maintenance to take maximum advantage of available outage time. Other important items relating to a coordination are the availability of repair parts, arrangement of manpower schedules and close supervison of necessary work. It is necessary to avoid simultaneous outage of large units and to maintain reasonable reserves during the maintenance period. Consideration should also be given to the state of interconnected reserves during periods of major maintenance projects.

Traditionally on many systems, maintenance outages take place between April and October, because at this time seasonal load drops generally are in excess of loss in effective capacity due to higher river water temperatures. Since the war, the difference in load peak between the winter and summer seasons has been greatly reduced, in large measure due to widespread installa-

tion of air conditioning. This has had a great effect on maintenance scheduling, for new ways must be found to offset this load condition or additional reserves must be installed.

In planning maintenance schedules, advantage may be taken of the most expeditious work periods, a factor which can be related to the general trend in system loads. With the shortening of the summer gap, indications are that the early spring months provide the best period for undertaking maintenance work. Another factor which may aid in providing reserve for maintenance of large units is the coordination of vacation periods of utility system customers. As an example, on group customer vacations the Duquesne Light Company provided as much as 50,000 kw for a two-week period over the July 4th holiday.

By reducing outage time for overhauling major units to a minimum, best advantage can be taken of available system reserves. At the same time, savings in operating economically can be achieved, since outage of the more efficient system units usually result in load transfer to units of less efficiency, thereby causing a loss in operating economically.

Extension of time intervals between overhauls is another factor in maintenance scheduling. Improvements in design have contributed materially to longer operation without inspection.

Mr. Bryson concluded by stating that systematic scheduling and maintenance planning aid in performing overhauling economically and effectively. Reduction of overhaul time and increasing service hours between overhauls, serve to reduce maintenance expenditures. Each system should study, develop and adopt the best practices for maintaining and overhauling major units.

Central Station Efficiency Control

A method of removing conjecture about station performance was proposed by **B. G. A. Skrotzki** of *Power* in a paper entitled "Steam-Electric Station Efficiency Control." When unexpected changes in monthly heat rate of a station take place, it is natural that those responsible for operation are concerned with the reasonableness of the result and the question of whether individual equipment has performed satisfactorily under the circumstances. A rigid form of analysis is required to determine the exact effect of each factor on the station heat rate. The method under discussion tells the operators whether or not equipment performs satisfactorily and shows clearly what factors cause unexpected variations in performance.

When this method of analysis is carried out, it is necessary to compare expected performance with actual performance. Close agreement indicates that the equipment is in satisfactory operating condition. If the heat rate is higher, maladjustments in the station cycle are indicated; if it is lower, there is a mathematical error in the computation of either the actual or expected heat rates.

By the magnitude of the deviation from expected performance, the operator can either be assured that his equipment is in order or be given reason to investigate the need for repairs. An index method may be used to establish a base heat rate for a station, which is a theoretical value that cannot be realized in practice. The plan of analysis is to change each of the operating conditions, one by one, from the standard (which is based upon the base heat rate) to the actual heat rate determined on the record of monthly operation. The difference in the two station heat rates is then a measure or index of the effect of that operating factor on the overall station heat rate under consideration.

This form of efficiency control has proved a very illuminating tool in station operation. It prevents chasing up "blind alleys" in which unexpected changes are attributed to but one factor. The true cause of variation in station heat rate generally involves several unrelated factors. Mr. Skrotzki estimated that, once the basic performance data have been prepared, it takes about three man-days per month to collect and classify log sheet data and figure the complete station heat-rate analysis in accordance with the proposed method.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Steam and Gas Turbines

By B. G. A. Skrotzki and W. A. Vopat

As might be expected from the relative use and state of development of the two types of prime movers, about 80 per cent of the text is given over to steam turbines and 20 per cent to gas turbines.

Intended primarily for operating engineers, the book is informative to anyone in the power field and might well be employed as a reference text for students, despite the absence of problems.

An elementary approach is employed in describing turbine types, followed by descriptions of commercial machines in greater variety than found in most other books on the subject. There follow chapters on lubrication, turbine governors, auxiliaries, maintenance and performance. The illustrations are simple and helpful, many of them having been previously published in special issues of *Power*, of which Mr. Skrotzki is an associate editor.

Under gas turbines, descriptions of the simple cycle and closed cycles include a discussion of means for increasing efficiency through intercooling, reheating, etc. The same approach to the subject is employed as in the preceding chapters in steam turbines.

There are 395 pages, 6 × 9 in., and the price is $5.

Elementary Pile Theory

By Harry Soodak and E. C. Campbell

To remove underlying theoretical bases of nuclear power plant from the realm of speculation and yet stay within the bounds of "declassified" material is a difficult task under present conditions. For the engineer this problem is further complicated by the necessity of learning an entirely new technical vocabulary containing such expressions as "slowing-down density," "neutron diffusion theory," the "albedo" or "reflection coefficient of the medium," "augmentation distance," "neutron cycle," "time-dependent pile equations" and "Fermi age." To this must be also added the requirement of understanding higher mathematics having a complexity unfamiliar to most engineers in the steam-power field.

The book is based on a series of lectures given in 1946–1947 by Dr. Soodak in connection with the Clinton Laboratories Training Program sponsored by the Monsanto Chemical Company in cooperation with the Atomic Energy Commission. It presents in brief form the fundamentals of the chain-reacting pile in which fast neutrons are produced by fission. An investigation is made of the behavior of neutrons given off in the act of fission, how they move about in space and how they are slowed down in matter.

For the engineer who is interested in some of the underlying theory of the nuclear power plant, who has the patience to work his way through unaccustomed areas of complex higher mathematics and who is willing to master new terminology, "Elementary Pile Theory" is recommended. There are 73 pages, and the book sells for $2.50.

Chemical Engineers' Handbook Third Edition

John H. Perry, Editor

This new edition of the Chemical Engineers' Handbook is the product of some 140 specialists under the general editorship of John H. Perry, technical investigator for E. I. du Pont de Nemours & Co. Most of the text has been revised to bring the technical information up to date and to include explanations of new developments in all branches of the industry. Several entirely new sections have been added.

The contents include sections on mathematics, physical and chemical data, flow of fluids, heat transmission, evaporation, gas absorption, diffusion, cooling towers and spray ponds, humidification and dehumidification, drying, mechanical separation, process control, materials of construction, fuels, furnaces and kilns, power generation, refrigeration, electricity, electrochemistry, accounting, safety and fire protection.

Supplementing the text are some 2000 charts, diagrams, cross-sections and flow sheets. There are 1884 pages, $7^1/_2 \times 9^7/_8$ in. and the price is $15.

Author's Guide

This little book of 77 pages has been prepared by the well-known publisher of technical books, John Wiley & Sons, for the guidance of those who prepare technical manuscripts and subsequently handle proof. In other words, it prescribes the correct and economical methods to be employed in editorial and production work for which an author is responsible. A very helpful compilation of "do" and "don't" procedure is appended.

Whether an author contemplates the preparation of a book, a technical article or an engineering society paper, this text should be most helpful. It is priced at $2.

Industrial Water Standards

This new compilation of 142 pages, prepared by A.S.T.M. Committee D-19 on Industrial Water, brings together in convenient form the various A.S.T.M. standard methods of sampling, analysis, and testing of industrial water for use of all those interested in this field. These methods have been developed particularly for the examination of water employed industrially in the generation of steam or for process or cooling purposes, and for the examination of deposits formed from such waters.

The publication includes twenty-six methods which cover sampling, analysis, corrosivity tests, methods of reporting and general testing methods.

C.E.-S. Elects Two New Vice-Presidents

H. G. Ebdon and William P. E. Ainsworth have been elected vice presidents of Combustion Engineering-Superheater, Inc.

Mr. Ebdon joined the Company in 1917 and since 1925 has served successively as manager of the Proposition Department; sales engineer, New York District Office; and assistant general sales manager. In 1941 he was appointed general sales manager of boilers and related equipment. He will continue in the latter capacity,

W. P. E. Ainsworth

H. G. Ebdon

working in association with Donald S. Walker, the Company's vice president and director of sales.

Mr. Ainsworth entered the employ of the Company in 1921 as a service engineer and later became manager of the Service and Erection Department. In 1939 he was appointed general purchasing agent and in 1942 was also made production manager. As a vice president he will continue in charge of purchasing and production for the Company's six American manufacturing plants.

Dr. Partridge Succeeds Dr. Hall

Dr. Everett P. Partridge has been named director of Hall Laboratories Inc., Pittsburgh, succeeding **Dr. R. E. Hall** who recently retired from its active direction after 25 years of service dating back to the founding of Hall Laboratories. His retirement was the occasion of a testimonial dinner which climaxed the silver-anniversary celebration of the company. However, Dr. Hall will continue his scientific work as consultant with the firm.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Radioisotopes

A most informative 28-page booklet entitled "Radioisotopes—A Survey" has been prepared by the Kellex Corp., a subsidiary of The M. W. Kellogg Co. There is a section devoted to the theory of isotopes, their means of identification, and their application in tracer methods having research value in the fields of medicine, biology, agriculture and fuel and steel technology. Current industrial employment of isotopes ranges from ways of improving de-icers for aircraft to the development of new catalysts for petroleum refining. Mention is also made of the increased availability of isotopes for industrial research and development.

Power Plant Instruments

Bulletin 90-1, prepared by Brown Instruments Div. of the Minneapolis-Honeywell Regulator Co., is a 31-page publication entitled "Advanced Instrumentation for Steam-Operated Generating Stations." Featured is a description of the constructional and operating details of the "Electronik" potentiometer, which is based on the continuous-balance principle. Pneumatic transmission which permits safe remote measurement of pressure, flow or liquid level is described. There is also a valuable two-page diagram of typical temperature and pressure measurement points in a steam generating unit and a turbine-generator.

Water Treatment

Dearborn Chemical Co. has released a 24-page, two-color booklet on water treatment and equipment. Entitled "Dearborn Industrial Water Treatment and Engineering Service," it covers the principles and fundamentals of providing trouble-free water in boiler plant operation for the prevention of scale, pitting and general corrosion, for producing pure dry steam and to avoid caustic embrittlement. It describes various testing apparatus and tells what tests to make and where to make them in a typical steam power plant.

Valve Selection Chart

A useful reducing-valve selection chart has been made available by Klipfel Valves, Inc., Division of Hamilton-Thomas Corp. By referring to the service for which a valve is intended and the reduced pressure limits, it is possible to make a correct valve selection easily. When used in conjunction with Bulletin 148, recently issued by the same company, the chart also enables the determination of proper valve size. The latter 24-page catalog includes illustrations and several types of reducing valves and price lists, dimensions, and weights.

Traveling Water Screens

The complete line of Rex traveling water screens is described in a 12-page bulletin, No. 50-36, published by Chain Belt Company. Types of screens available, features of particular designs, and factors in selection of screens are discussed in this well-illustrated bulletin which covers a relatively unpublicized phase of steam power plant practice.

Mechanical Draft Fans

An unusually informative 36-page catalog on mechanical-draft fans has been prepared by Buffalo Forge Co. Not only is the bulletin effectively illustrated by photographs of typical installations and details of mechanical construction, but it also contains much valuable engineering reference material. Sections of the catalog are devoted to single- and double-width induced-draft fans, rotors, shafts and couplings, bearings, cinder-eliminating fans, forced-draft fans, combination-draft fans, dampers and vanes, fan performance characteristics and types of fan drive.

Flow Meters

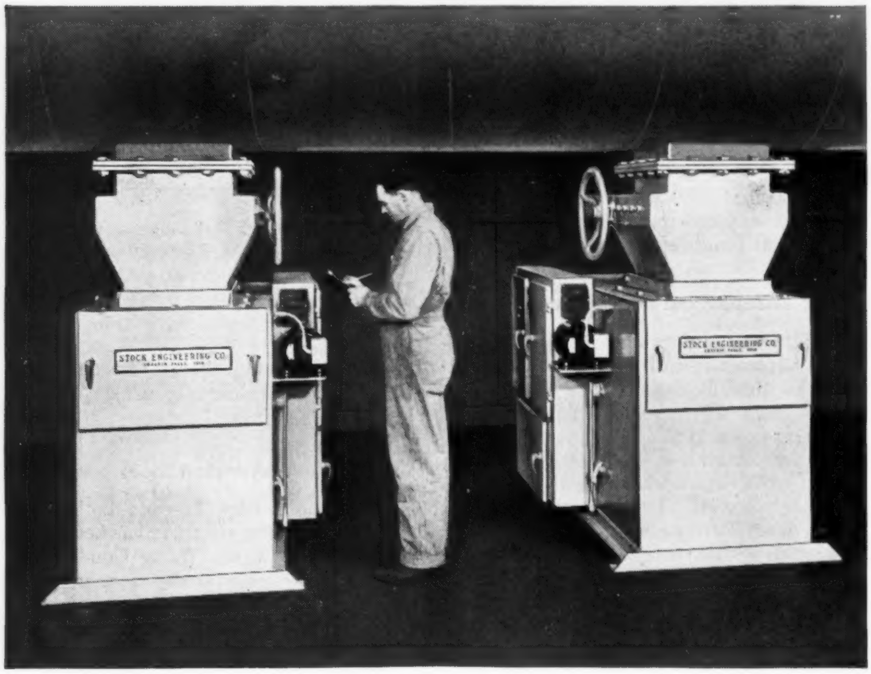
Catalog 37, a 12-page bulletin, illustrates and describes a new line of mercury manometer flow meters manufactured by the Fischer & Porter Co. The attractively illustrated catalog shows details and typical applications of the meters, which can measure the flow rate of liquids, vapors and gases in piping systems and may be arranged for recording, indicating, pneumatic remote transmitting or automatic controlling functions at pressures up to 1500 psig.

Air Compressors

The Ingersoll-Rand Co. has released a 20-page, three color bulletin on its Type XLE electric-driven compressor, which is said to incorporate both a "new look" and a new idea in air-compressor design. Features of the new design are explained in considerable detail in the new bulletin, which is a good example of an exceptionally informative technical catalog.

Water Softeners

A comprehensive 36-page bulletin on hot-process water softeners has been made available by Graver Water Conditioning Co. In the introductory section boiler plant problems caused by water impurities are concisely explained, twelve methods of water treatment are outlined, and advantages of the hot-process method are described, along with the chemistry of that process. Two basic designs of hot-process softeners are explained, together with six adaptations to meet specific plant conditions. There are more than 30 diagrams of hot-process designs and flow charts, plus many typical installation photos in this well-prepared and useful reference bulletin.



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